REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 0704-0188*

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	30.May.02	DISSERTATION

4. TITLE AND SUBTITLE
TWO-PERSON BRAGAINING UNDER INCOMPLETE INFORMATION: AN EXPERIMENTAL STUDY OF NEW MECHANISMS

5. FUNDING NUMBERS

6. AUTHOR(S)
MAJ PARCO JAMES E

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
UNIVERSITY OF ARIZONA

8. PERFORMING ORGANIZATION REPORT NUMBER
CI02-72

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
THE DEPARTMENT OF THE AIR FORCE
AFIT/CIA, BLDG 125
2950 P STREET
WPAFB OH 45433

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Unlimited distribution
In Accordance With AFI 35-205/AFIT Sup 1

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

20020702 017

14. SUBJECT TERMS

15. NUMBER OF PAGES
253

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTR

THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the Final Examination Committee, we certify that we have read the dissertation prepared by James Edward Parco entitled Two-Person Bargaining Under Incomplete information: An Experimental Study of New Mechanisms and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

Amnon Rapoport — Date: Dec. 11, 2001

Massimo Piatelli-Palmarini — Date: 12/11/01

Lisa D. Ordóñez — Date: 12/11/01

Stanley Reynolds — Date: 12/11/01

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Amnon Rapoport
Dissertation Director — Date: Dec. 11, 2001

STATEMENT BY AUTHOR

This dissertation has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this dissertation are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances however, permission must be obtained from the author.

SIGNED: James S. Parcs

ACKNOWLEDGMENTS

I am extraordinarily grateful for the trust and encouragement of Chuck Yoos, Steve Green, Jim Woody and Rita Jordan at the United States Air Force Academy for having faith in my abilities and granting me the opportunity to pursue my studies through the Air Force Institute of Technology's Civilian Institution program. Without the benevolent support of these individuals and organizations, this manuscript would have not been possible.

I shall forever be indebted to Massimo Piatelli-Palmarini, Bill Stein, Darryl Seale, Terry Daniel, Lisa Ordóñez, Ryan Murphy and Maya Rosenblatt for their invaluable advice and friendship over the past three years. I'd also like to express my sincere appreciation to Vernon Smith, Kevin McCabe, Stan Reynolds and Jim Cox for their guidance and gracious support through the Economic Science Laboratory and ESL Advisory Committee.

Additionally, I would like to acknowledge the financial support for this research through Amnon Rapoport, Darryl Seale, and Rami Zwick from a grant by the Hong Kong Research Grants Council, Project No. HKUST6225/99H.

Finally, I wish to express my deepest gratitude to the two men who have had the most profound impact on how I've come to see the world--Kevin Davis and Amnon Rapoport. No words can describe the respect and admiration I developed for them as mentors, teachers and friends. It has been an honor and a privilege...

To be literate in the Modern Age, you need to have a general understanding of Game Theory.
-Paul Samuelson

DEDICATION

To my mother for her compassion and inspiration,

To my father for his work ethic and sense of humor,

To my brother for his tenacity and courage,

To my mother-in-law and father-in-law for their steadfast support,

To my beloved wife for everything that she is, says, and does,

And to my little girls for never letting me forget what's important...

Sadly, the course of the world forever changed on the morning of September 11th, 2001 and we must never forget the thousands of innocent Americans whose lives were viciously taken from us in an unprovoked attack on democracy. Liberty has a price that must be paid by all and the time has come for us once again to make the necessary sacrifices required to provide our children with the unalienable opportunity to live in a Free Society.

Let every nation know, whether it wishes us well or ill, that we shall pay any price, bear any burden, meet any hardship, support any friend, oppose any foe to assure the survival and the success of liberty.
- John F. Kennedy

I dedicate this work to all those who are committed to preserving the American ideal.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS 15

LIST OF TABLES 18

ABSTRACT 20

CHAPTER I: INTRODUCTION 22

A. OVERVIEW 22

B. RELEVANT LITERATURE REVIEW:
THEORY AND EXPERIMENTAL EVIDENCE 26

(1) Theory 27

(2) Experimental Evidence 28

C. METHODOLOGY 36

(1) Procedure 38

(2) Other General Considerations 39

D. INTRODUCTION OF EXPERIMENTS 40

(1) Baseline Study 40

(2) Bonus Mechanism 40

(3) Two-stage Mechanism 41

(4) Varying-*k* Mechanism 42

E. INTEGRATION OF THE EXPERIMENTS THROUGH LEARNING MODELS 42

TABLE OF CONTENTS – CONTINUED

CHAPTER II: BASELINE STUDY 45

A. INTRODUCTION 45

B. THEORY 46

C. METHOD 49

(1) Subjects 49

(2) Procedure 49

D. RESULTS 50

(1) Comparison with Previous Studies: DSR Experiment 1 50

(2) Individual Data 51

(a) Baseline Condition, Buyers 51

(b) Baseline Condition, Sellers 54

(3) Aggregate Analysis 55

(4) Baseline Discussion 57

CHAPTER III: BONUS MECHANISM 58

A. INTRODUCTION 58

(1) Theoretical Solution 58

(2) Limitation 59

(3) Overview of Bonus Study 60

B. THEORY 62

C. METHOD 64

(1) Subjects 64

TABLE OF CONTENTS – CONTINUED

(2) Procedure 65

D. RESULTS 67

(1) Between Treatment Comparisons 68

(2) Individual Data 68

(a) Partial Bonus (Buyers) 68

(b) Partial Bonus (Sellers) 72

(c) Full Bonus (Buyers) 72

(d) Full Bonus (Sellers) 75

(e) Reframed Full Bonus (Buyers) 76

(f) Reframed Full Bonus (Sellers) 78

(3) Typology of Decisions 80

(4) Regression Analysis 83

(5) Aggregate Results 87

(6) Efficiency Analysis 89

(7) Theoretical Simulation Analysis 91

(8) Bonus Discussion 97

CHAPTER IV: TWO-STAGE MECHANISM 101

A. INTRODUCTION 101

B. THEORY 101

C. METHOD 104

(1) Design Considerations 104

TABLE OF CONTENTS - CONTINUED

(2) Subjects 106

(3) Procedure 107

D. RESULTS 108

(1) Within and Between Treatment Comparisons 109

(2) Individual data 111

(a) Stage 1 111

(i) Inexperienced, Buyers 111

(ii) Inexperienced, Sellers 115

(iii) Sophisticated, Buyers 116

(iv) Sophisticated, Sellers 117

(v) Experienced, Buyers 118

(vi) Experienced, Sellers 120

(b) Stage 2 123

(i) Inexperienced, Buyers 123

(ii) Inexperienced, Sellers 125

(iii) Sophisticated, Buyers 127

(iv) Sophisticated, Sellers 128

(v) Experienced, Buyers 129

(vi) Experienced, Sellers 129

(3) Aggregate Results 132

(4) Two-stage Discussion 146

TABLE OF CONTENTS – CONTINUED

CHAPTER V: VARYING-*k* MECHANISM 150

A. INTRODUCTION 150

(1) Overview of Varying-*k* Study 150

(2) Experimental Design 151

B. THEORY 152

C. METHOD 156

(1) Subjects 156

(2) Procedure 157

D. RESULTS 158

(1) Within Treatment Comparisons 158

(2) Individual Data 159

(a) Dominating Player Treatment 159

(i) Condition BB (Buyers) 159

(ii) Condition BB (Sellers) 162

(iii) Condition SS (Buyers) 162

(iv) Condition SS (Sellers) 166

(b) Balanced Power Treatment 165

(i) Condition BS (Buyers) 165

(ii) Condition BS (Sellers) 165

(iii) Condition SB (Buyers) 170

(iv) Condition SB (Sellers) 170

TABLE OF CONTENTS - CONTINUED

(3) Aggregate Analysis 170
(4) Simulation Analysis 177
(5) Varying-*k* Discussion 181

CHAPTER VI: LEARNING 183
A. INTRODUCTION 183
B. HISTORICAL PERSPECTIVE OF LEARNING MODELS 184
(1) The Early Years 184
(2) Modern Modeling Approaches 185
(3) Model Comparison 187
C. A REINFORCEMENT-BASED ADAPTIVE LEARNING MODEL FOR TWO-PERSON BARGAINING UNDER INCOMPLETE INFORMATION 190
(1) The DSR Model 190
(2) The Two-stage Refinement 192
(3) Estimation Procedures 193
(4) Results: Moderate Information Asymmetry 193
(a) Buyer Model 193
(i) Baseline Mechanism 193
(ii) Bonus Mechanism 194
(iii) Two-stage Mechanism 195
(b) Seller Model 196
(i) Baseline Mechanism 196

TABLE OF CONTENTS – CONTINUED

(ii) Bonus Mechanism 197

(iii) Two-stage Mechanism 198

(5) Results: Extreme Information Asymmetry 206

(a) Varying-*k*, Information-Advantaged 206

(i) Buyer Model 206

(ii) Seller Model 206

(b) Varying-*k*, Information-Disadvantaged 211

(i) Buyer Model 211

(ii) Seller Model 212

(6) Learning Model Discussion 212

CHAPTER VII: CONCLUSION 216

A. BONUS 216

B. TWO-STAGE 217

C. VARYING-*k* 218

APPENDIX A. SUMMARY OF EXPERIMENTATION 221

APPENDIX B. INSTRUCTIONS, BASELINE GAME 222

APPENDIX C. INSTRUCTIONS, PARTIAL BONUS 225

APPENDIX D. INSTRUCTIONS, FULL BONUS 228

APPENDIX E. INSTRUCTIONS, REFRAMED FULL BONUS 231

TABLE OF CONTENTS – CONTINUED

APPENDIX F. INSTRUCTIONS, TWO-STAGE 234

APPENDIX G. INSTRUCTIONS, VARYING-*k*, CONDITION BS 237

APPENDIX H. INSTRUCTIONS, VARYING-*k*, CONDITION BB 240

APPENDIX I. INSTRUCTIONS, VARYING-*k*, CONDITION SS 243

APPENDIX J. INSTRUCTIONS, VARYING-*k*, CONDITION SB 246

APPENDIX K. HUMAN SUBJECTS COMMITTEE APPROVAL 249

REFERENCES 250

LIST OF ILLUSTRATIONS

FIGURE 2-1. Linear Equilibrium Strategies, Two-Person Bargaining, $k = 1/2$ 48

FIGURE 2-2a. Baseline, Buyers 52

FIGURE 2-2b. Baseline, Sellers 53

FIGURE 2-3. Best Fitting OLS Regression Functions by Block 56

FIGURE 3-1. Linear Equilibria for the Bonus Conditions 64

FIGURE 3-2a. Partial Bonus, Buyers 70

FIGURE 3-2b. Partial Bonus, Sellers 71

FIGURE 3-3a. Full Bonus, Buyers 73

FIGURE 3-3b. Full Bonus, Sellers 74

FIGURE 3-4a. Reframed Full Bonus, Buyers 77

FIGURE 3-4b. Reframed Full Bonus, Sellers 79

FIGURE 3-5. Categorization of Offer Types 82

FIGURE 3-6. Mean Squared Deviation Running Average (step 10) Between Offer and Reservation Value 83

FIGURE 3-7. Regression Plots by Block 88

FIGURE 3-8. Regression Plots by Player Type 89

FIGURE 4-1. Information Updating of the Linear Equilibrium Strategies 103

FIGURE 4-2a. Inexperienced Buyers, Stage 1 113

FIGURE 4-2b. Inexperienced Sellers, Stage 1 114

FIGURE 4-3a. Sophisticated Buyers, Stage 1 116

FIGURE 4-3b. Sophisticated Sellers, Stage 1 117

FIGURE 4-4a. Experienced Buyers, Stage 1 119

LIST OF ILLUSTRATIONS - CONTINUED

FIGURE 4-4b. Experienced Sellers, Stage 1 121

FIGURE 4-5a. Inexperienced Buyers, Stage 2 124

FIGURE 4-5b. Inexperienced Sellers, Stage 2 126

FIGURE 4-6a. Sophisticated Buyers, Stage 2 127

FIGURE 4-6b. Sophisticated Sellers, Stage 2 128

FIGURE 4-7a. Experienced Buyers, Stage 2 130

FIGURE 4-7b. Experienced Sellers, Stage 2 131

FIGURE 4-8. Running Average of Stage 1 Offers by Condition 136

FIGURE 4-9. Best Fitting OLS Stage 2 Bid Functions, Buyers 142

FIGURE 4-10. Best Fitting OLS Stage 2 Ask Functions, Sellers 144

FIGURE 4-11. Predicted versus Observed Bargaining Efficiency 146

FIGURE 5-1. Linear Equilibrium Strategies for Varying-k Conditions 155

FIGURE 5-2a. Condition BB, Buyers, F~[0,20], G~[0,200], k=1 160

FIGURE 5-2b. Condition BB, Sellers, F~[0,20], G~[0,200], k=1 161

FIGURE 5-3a. Condition SS, Buyers, F~[0,200], G~[180,200], k=0 163

FIGURE 5-3b. Condition SS, Sellers, F~[0,200], G~[180,200], k=0 164

FIGURE 5-4a. Condition BS, Buyers, F~[0,20], G~[0,200], k=0 166

FIGURE 5-4b. Condition BS, Sellers, F~[0,20], G~[0,200], k=0 167

FIGURE 5-5a. Condition SB, Buyers, F~[0,200], G~[180,200], k=1 168

FIGURE 5-5b. Condition SB, Sellers, F~[0,200], G~[180,200], k=1 169

FIGURE 5-6. Dominating Player Treatment Regression Summary 172

LIST OF ILLUSTRATIONS – CONTINUED

FIGURE 5-7. Balanced Power Treatment Regression Summary 172

FIGURE 6-1. Learning Parameter Results Across Experiments 214

FIGURE 6-2. Gain Parameter (w^{+}) Results 215

LIST OF TABLES

TABLE 2-1. Spline Regression Results, Buyers, by Block 55

TABLE 2-2. Regression Results, Sellers, by Block 56

TABLE 3-1. Bonus Mechanism Experimental Design 65

TABLE 3-2. Percentage of Offer Types by Condition 81

TABLE 3-3. Regression Results, Sellers 84

TABLE 3-4a. Spline Regression Results, Buyers, Block 1: Trials 1-25 86

TABLE 3-4b. Spline Regression Results, Buyers, Block 2: Trials 26-50 86

TABLE 3-4c. Spline Regression Results, Buyers, Trials 1-50 86

TABLE 3-5. Efficiency Results by Condition 90

TABLE 3-6. Deal Simulation 93

TABLE 3-7a. Earnings Simulation, No Bonus and Partial Bonus Conditions 94

TABLE 3-7b. Earnings Simulation, Full Bonus and Reframed Full Bonus Conditions .. 95

TABLE 4-1. Two-stage Experimental Design 105

TABLE 4-2a. Treatment Comparisons by Stage 1 Agreements 110

TABLE 4-2b. Treatment Comparisons Across Stages 111

TABLE 4-3. Percentage of Offer Types by Condition 133

TABLE 4-4. Mean Stage 1 Offers by Condition 134

TABLE 4-5. Stage 1 Agreements 137

TABLE 4-6. Total Deals (Stage 1 and 2) Across Trials 139

TABLE 4-7a. Spline Regression Results, Buyers, Block 1: Trials 1-25 (Stage 2 only) 141

TABLE 4-7b. Spline Regression Results, Buyers, Block 1: Trials 26-50 (Stage 2 only) . 141

TABLE 4-7c. Spline Regression Results, Buyers, Block 1: Trials 1-50 (Stage 2 only) 141

LIST OF TABLES – CONTINUED

TABLE 4-8. Regression results, Sellers (*Stage 2 only*) 143

TABLE 4-9. Two-stage Earnings Summary 145

TABLE 5-1. Experimental Design, Varying-*k* 151

TABLE 5-2. Mean Absolute Percentage Error Between Offers and LES 158

TABLE 5-3. Regression Results, Varying-*k* Conditions 175

TABLE 5-4. Deal Analysis, Varying-*k* 176

TABLE 5-5. Dominating Player Treatment: Condition BB Earnings Simulation 178

TABLE 5-6. Dominating Player Treatment: Condition SS Earnings Simulation 179

TABLE 5-7. Balanced Power Treatment: Condition BS Earnings Simulation 180

TABLE 5-8. Balanced Power Treatment: Condition SB Earnings Simulation 181

TABLE 6-1. Learning Model Results, Baseline Condition 199

TABLE 6-2a. Learning Model Results, Partial Bonus Condition 200

TABLE 6-2b. Learning Model Results, Full Bonus Condition 201

TABLE 6-2c. Learning Model Results, Reframed Full Bonus Condition 202

TABLE 6-3a. Learning Model Results, Two-stage Inexperienced Condition 203

TABLE 6-3b. Learning Model Results, Two-stage Sophisticated Condition 204

TABLE 6-3c. Learning Model Results, Two-stage Experienced Condition 205

TABLE 6-4a. Learning Model Results, Dominating Player Treatment, Condition BB 207

TABLE 6-4b. Learning Model Results, Dominating Player Treatment, Condition SS 208

TABLE 6-4c. Learning Model Results, Balanced Power Treatment, Condition BS 209

TABLE 6-4d. Learning Model Results, Balanced Power Treatment, Condition SB 210

TABLE 6-5. Learning Model Summary Results 212

TWO-PERSON BARGAINING UNDER INCOMPLETE INFORMATION:

AN EXPERIMENTAL STUDY OF NEW MECHANISMS

by

James Edward Parco

A Dissertation Submitted to the Faculty of the

COMMITTEE ON BUSINESS ADMINISTRATION

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY
WITH A MAJOR IN MANAGEMENT

In the Graduate College

THE UNIVERSITY OF ARIZONA

2002

ABSTRACT

New theoretical developments and recent experimental studies involving the sealed-bid k-double auction mechanism for bilateral bargaining under incomplete information have raised new questions about procedures that induce efficient bargaining behavior and about the applicability of extant adaptive learning models. It is now generally accepted that a theory of bargaining behavior for individuals who typically do not meet the stringent assumptions about common knowledge of rationality cannot be complete without systematic empirical investigations of the properties of the various mechanisms that structure bargaining.

The aim of this dissertation is to critically explore the extent to which efficient bargaining outcomes can be achieved while dynamically accounting for individual behavior across repeated play of the game. In the first study, an endogenous bonus is introduced into the baseline single-stage game. Although theoretically doing so induces truth-telling behavior for both players, the experimental data provide very limited support. In the second study, the baseline game is extended by incorporating an additional, costless period of bargaining, thereby giving players an increased opportunity to reveal information about their respective reservation values. The data show that subjects quickly learn not to reveal information about their private valuation despite the increased opportunity to bilaterally improve efficiency. Finally, the third study investigates behavior sensitivity to variation in the trading parameter, k. Instead of following the historical precedent of setting $k={}^{1}/_{2}$, extreme values of k are invoked in an asymmetric information environment endowing a player with exclusive price-setting power. Although theoretical analysis suggests that expected profits for a seller (buyer) decreases (increases) in k, experimental results show that under conditions of dramatic information asymmetry, the observed share of the surplus is

much smaller for the player with price setting power if countered with an information disadvantage resulting in poor support of the LES. Furthermore, the price setting power effectively counters the information disparity advantage demonstrated in previous studies. Results from a previously proposed reinforcement-based adaptive learning model not only demonstrate robust applicability across studies but also the model's ability to account remarkably well for the dynamics of play across iterations of the stage game.

CHAPTER I: INTRODUCTION

> A two-person bargaining situation involves two individuals who have the opportunity to collaborate for mutual benefit in more than one way... the negotiation process must be formalized and restricted but in such a way that each participant is still able to utilize all the essential strengths of his position. (Nash, 1950)

A. Overview

One of the most intriguing problems to academics and practitioners across disciplines is the bargaining problem: how to achieve conflict resolution that is mutually acceptable to all parties involved. Considering the bargaining problem from the perspective of two players, say a buyer and a seller, it is generally understood that a solution which yields a positive payoff to both players is better than a solution that yields nothing to either. Conventional theoretical solutions to simultaneous bargaining games (Chatterjee and Samuelson, 1983; Myerson and Satterthwaite, 1983; Leininger et al., 1989; Satterthwaite and Williams, 1989; Linhart et al, 1992) dictate that players behave strategically and in some cases, 'walk away' from an otherwise profitable agreement. Previous experimental work on bilateral bargaining games under incomplete information (Radner and Schotter, 1989; Rapoport and Fuller, 1995; Rapoport, Daniel, and Seale, 1998; Valley, Moag, and Bazerman, 1998; Daniel, Seale, and Rapoport, 1998; Seale, Daniel, and Rapoport, 2001 -- hereafter referred to as RS, RF, RDS, VMB, DSR and SDR, respectively) has revealed that players reach inefficient ex post outcomes when engaged in such games. That is, not all profitable deals occur resulting in lost profits to both buyer and seller. However, because players are in

possession of private information, there exist no effective control mechanisms to prevent players from strategically misrepresenting their "reservation values" or their minimal demands (i.e. the most a buyer is willing to pay and the least a seller is willing to take to independently guarantee a non-negative outcome). Although players could jointly do better if both buyer and seller bid/ask their respective reservation values, they don't since truthful revelation is not incentive-compatible. A mechanism is said to be incentive-compatible if honest bidding results in a Bayesian-Nash equilibrium. Because the sealed-bid *k*-double auction is not an incentive-compatible mechanism, neither player can maximize his expected utility by making an offer of his true reservation value, given that he expects his co-bargainer to do the same. Zartman refers to the trade-off between making an offer that truthfully reflects the reservation value and making strategic offers (exaggerated offers -- lower for buyers, higher for sellers) as the "toughness dilemma:" the more strategically a (tougher) a party acts, the greater its chances for an agreement close to its position but the greater chances of no agreement at all, whereas the more yielding (softer) a party acts, the greater chances are for an agreement albeit a less favorable one (1987).

Any complete theory of the functioning and efficiency of markets ought to have at its base a theory of how bargaining determines who trades what at what prices. Because such a theory of bargaining concerns individuals who are known to be boundedly-rational and have limitations on their information processing capability, it cannot be complete without experimental investigation of the properties of mechanisms used to structure bargaining, the effects of experience on bargaining behavior and individual differences. Some markets are inherently small. One would like to understand how the choice of rules in such markets affects

the proportion of the potential gains from trade realized through bargaining, and the division of the realized gain, if trade takes place, between the seller and buyer. The ensuing experiments are concerned with this issue. Further, if the modified payoff structures have the desired effect on bargaining efficiency, similar procedures could be implemented in practice.

The notion of efficiency is paramount in mechanism design. A prime desideratum is that any proposed mechanism should maximize efficiency. A bargaining mechanism is considered to be *ex post efficient* if <u>all</u> possible gains from trade are realized. Likewise, an *inefficient* outcome is defined as not achieving a deal when in fact a deal was possible without either of the players incurring a loss (reservation value of the buyer, v_b, weakly exceeds the reservation value of the seller, v_s). A related concept is *ex ante efficiency* whereby players can maximize individual earnings if each makes a truthful offer. However, as previously noted, truthful bidding is not incentive-compatible. Given that a player's co-bargainer makes a truthful offer, she should submit a strategic offer. And the greater her exaggeration, the less likely that an agreement will be reached. Nevertheless, it is still in her best interest to "shave" her offer which will force a more favorable trade price and, subsequently, higher earnings. In the alternative case, given that a player's co-bargainer makes a non-truthful (strategic) offer, she should still submit a strategic offer. Again, although making a strategic offer will reduce the likelihood of consummating a deal, it will force a more favorable trade price and prevent the co-bargainer from taking advantage of her. Although infinite equilibria often exist in typical bargaining problems, a particular interesting equilibrium (Bayesian-Nash) turns out to be a pair of linear functions (Chatterjee and Samuelson, 1983 -- hereafter CS). Not only is this pair of functions unique within the class of linear strategies but it also yields the maximum expected value of the game when the distributions of reservation values

are uniform and have the same support. This equilibrium, commonly known as the LES (linear equilibrium strategies), forms the theoretical basis for the following studies.

Fundamental to the sealed-bid bilateral bargaining paradigm under investigation is an environment characterized by two-sided incomplete information where each player knows his own reservation value (type) but does not know his co-bargainer's reservation value. Following Harsanyi's approach to modeling noncooperative games of incomplete information (1967; 1968), the beliefs that each player has about his co-bargainer's reservation value are modeled by a (prior) probability distribution. The key uncertainty in these bargaining games is that each player does not know the reservation value of the other. The bargainers only know the range from which these values are randomly selected. Thus, regardless of the co-bargainer's offer, it is in each player's own best interest to make a strategic offer. The LES turns out to be a Bayesian-Nash equilibrium which is Pareto deficient since (1) neither buyer nor seller could improve his/her outcome by unilateral deviation; yet, (2) both players would benefit through mutual deviation. This type of equilibrium solution generates inefficient outcomes by motivating players to make strategic offers to improve individual outcomes while foregoing mutually profitable deals. The magnitude of the inefficiency can be substantial, depending on the parameters of the distributions of the reservation values. In stark contrast to individual decision-making, the concept of maximum expected value from an individual perspective doesn't necessarily provide the optimal solution if considering the joint outcome in an interactive decision-making task. Thus, the Bayesian-Nash equilibrium concept is both important and necessary to benchmark observed behavior and judge outcome efficiency.

B. Relevant Literature Review: Theory and Experimental Evidence

The most common benchmark for experimental investigations of interactive decision behavior is the Nash equilibrium solution concept. Often, the solution is unique forming acute predictions of behavior. However, the bilateral bargaining game of incomplete information considered here has a very large set of equilibria (Leininger et al., 1989). For instance, any pair of offers in which the buyer bids the same amount as the seller's ask is an equilibrium. Thus, when the set of equilibria is large, any prediction based solely on general equilibrium theory is weak given that there exists a solution to support almost any observed behavior. In these cases, further refinements are necessary to predict which particular equilibria, if any, are superior and what dynamic processes lead to these observed states. In the case of the bilateral bargaining game of incomplete information, CS published a seminal paper documenting the very desirable properties of the LES equilibrium solution (1983). Not only is the LES the unique linear function (or piece-wise linear under information asymmetry) of the player's reservation value, but also it has been proven that this particular equilibrium yields the highest expected gains from trade of any equilibrium of any bargaining mechanism for symmetric uniform common priors (Myerson and Satterthwaite, 1983). Later experimental work (RS, RF, DSR, VMB, RDS and SDR) has generally supported the LES. Because of the multiplicity of equilibria, equilibrium theory provides no recommendation for implementing the sealed-bid mechanism in practice (Leininger et al., 1989). However, with the support of the LES through experimental results, the sealed-bid mechanism has emerged as a practical procedure with reliably predictable and unique linear equilibria. Thus, because the LES (1) provides the maximum gains from trade in equilibrium; (2) has shown through previous experimental investigation to account well for observed behavior; and, (3) is simple

to calculate and analyze, static analysis of the following experiments will be constrained to the LES.

(1) Theory. Consider the following scenario where the seller has a single object that she may sell to the buyer if an acceptable price, p, is agreed upon. Assume that v_b denotes the buyer's reservation value and v_s denotes the seller's reservation value. Players are assumed to be rational, risk-neutral, expected utility maximizers and their utility functions are normalized so that if no trade occurs then the utility of each is zero. Each player's reservation value is a random variable whose value is contained in some interval. The reservation values v_s and v_b for the seller and buyer, respectively, are randomly and independently drawn from separate uniform distributions, F and G. Although each player's distribution is assumed to be common knowledge, the actual reservation values for each trial are private and never revealed during any phase of the game. Under the sealed-bid k-double auction mechanism, the seller submits an offer to sell, $s=S(v_s)$, and simultaneously the buyer submits an offer to buy, $b=B(v_b)$. If $b \geq s$, then trade occurs with no delay at trade price p and the gains from trade for the seller and buyer are $p - v_s$ and $v_b - p$, respectively. Otherwise, the game ends in disagreement and each player earns nothing.

Development of the LES provided the basis for experimental inquiry into bilateral bargaining by describing linear strategies for both the buyer and seller in a single parameter model. This parameter, k, is the ratio between the buyer's offer and the seller's offer which determines the trade price, p, given that $b \geq s$ as $p=kb+(1-k)s$. Thus, if $k=0$ then $p=s$. In this case, the seller sets the trade price and the buyer retains only veto power. On the other hand if $k=1$, $p=b$ and the opposite case holds -- the buyer sets the trade price and the seller retains only

veto power. If $k=1/2$, trade occurs with no delay at the price $p=(b+s)/2$. If $b<s$, then no trade occurs. Setting $k=1/2$ will be referred to as the "midpoint rule."

(2) Experimental Evidence.[1] Radner and Schotter (1989) conducted the first experimental research using the sealed-bid k-double auction mechanism. They ran eight experiments (manually, without computers) for fifteen rounds each (except for their sixth experiment which consisted of forty rounds). RS were primarily motivated to ascertain whether or not players used linear strategies, and if so, whether they used the LES predicted by CS. RS Experiments 1, 2 and 5 turned out to be the best tests of the LES.[2] RS Experiment 1 was the baseline employing identical prior distributions $F \sim G \sim$uniform[0,100] for buyer and seller. RS Experiment 2 was a replication of Experiment 1 except that after each trial, the trade price information from all bargaining pairs was posted on the black board for all subjects to see. Each experiment consisted of fixed-pairing of buyers and sellers (approximately twenty subjects per session) and consisted of fifteen trials. The results from the RS study were noteworthy since they indicated that the behavior of the experimental subjects was indeed consistent with the LES, especially when the underlying probability distributions were uniform.[3] However, many questions remained, such as how behavior would change with additional trials. A major problem with the RS study is that they used fixed-pairing of subjects allowing for reputation effects. This confounded their analysis of testing a single-stage model (the LES) with data from a repeated game. Additionally, all of their experiments had symmetric support of the uniform priors.

---

[1] See Appendix A (page 221) for a summary table of previous experimental work.

[2] RS Experiment 5 was identical to Experiment 1 except it used non-uniform priors, skewed to increase the probability of consummating a deal. See RS for further discussion.

[3] RS noted that when the probability distributions were not uniform, step-function equilibria began to evolve. However, because of their 15 trial experimental design, limited data were available to analyze this finding.

Rapoport and Fuller (1995) published the results of two single-stage experiments to answer some of the questions raised by RS. RF's initial point of departure from the RS study was that of methodology: how to test a static model of a two-person game. RS had fixed the pairing of subjects throughout the trials. However, RF argued "if practical considerations dictate iterations of the game, the common procedure is to have the subjects play the game against different opponents on successive rounds." (1995) RF based their experiments on a randomized design where the pairing of players changed between trials mitigating reputation effects. A second difference between the two studies focused on the conjecture of RS regarding the appearance of step-wise bidding functions. In contrast to RS, RF hypothesized that the step-wise functions could be attributed to learning or possibly to the degree of overlap of the prior distributions supports. RF also differed in their design by directly eliciting strategies from the players after participation in the game to look at bidding intentions prior to actual offers.

RF experiments each consisted of ten subjects per group (five buyers and five sellers) and lasted for twenty-five trials constituting Phase I. Phase II utilized the strategy method to elicit subject responses for a range of randomly presented reservation values. Although direct comparison of the phases is confounded by experience and response type, both phases demonstrated support for the linear strategies: buyers tended to underbid and sellers asked for more than their respective reservation values. However, the players did not make offers as aggressively as predicted by the LES model with the preponderance of the data lying between the LES function and the truth-telling function. For about half of the subjects, the Truthful Revelation Model (TRM) better accounted for the observed data whereas the LES tended to account better for the other half. However, by eliciting the

strategies (Phase II), the offers became monotonic and more closely approximate a truth-telling strategy. The introduction of asymmetry between players achieved by drawing reservation values from distributions defined over overlapping intervals (F~uniform[0,100], G~uniform[0,200]) induced a piece-wise linear function and support for the strict linearity hypothesis declined. Additionally, "step-like" functions began to appear, just as the LES predicts.

Although the RF study was critical in expanding the experimental inquiry into the LES, their focus relied on a static model. Fundamental to expanding knowledge into human behavior is to dynamically capture the learning processes of the subjects. Daniel, Seale, and Rapoport (DSR, 1998) continued the approach of RF focusing on evaluating the descriptive power of the LES model in lieu of comparing it to a truth-telling model. DSR drastically increased the information disparity between the players (F~uniform[0,20] and G~uniform[0,200]) and proposed an adaptive learning model to account for the change in bidding behavior over the course of the game.

Methodologically, DSR differed from both RS and RF in that all of their experiments were conducted via networked computers.[4] Because of the decreased administrative effort afforded by automation, DSR was able to double the number of trials to fifty and the number of subjects per group to twenty. Also, each subject could access his own history of all trials completed. Because of these major differences, DSR's Experiment 1[5] was used as a baseline to compare to RF Experiment 2. Results of the comparison were remarkably consistent and showed no significant differences between the studies using different data

[4] Instead of face to face, as both RS and RF had done.

[5] Subsequently chosen as the model for the Baseline study – see Chapter II.

collection methods. Observed individual behavior from DSR Experiment 1 sellers showed a similar number of truth-tellers when compared to RF Experiment 2. However, none of the DSR Experiment 1 buyers exhibited truthfully revealing behavior.

DSR Experiment 2 results illustrated the aggressiveness of the information-advantaged players[6] (buyers) as F and G became more disparate. In fact, the information-disadvantaged players (sellers) not only earned less as a group than they would have under a truthful revelation strategy, they also earned significantly less than they would have had they followed the LES. This was a very important finding documenting for the first time how an information advantage yielded more power to the advantaged player than predicted in the bilateral bargaining mechanism under incomplete information.

DSR also introduced an adaptive learning model, which accounted for most of the trial-to-trial variability of the information-advantaged players buyers quite well. However, it didn't do as well with the information-disadvantaged sellers. DSR's learning model shared many of the principles found in the Roth-Erev model (1995) while making no cognitively demanding assumptions.[7] Both models, in fact, follow from the learning model approach pioneered by Bush and Mosteller (1955). Specifically, the DSR learning model strives for parsimony while capturing both the Law of Effect[8] (Thorndike, 1898) and the Power Law of

[6] An "information advantaged" player is one who has a wider range of possible reservation values (assuming a uniform distribution) compared to that of his co-bargainer. Conversely, an "information disadvantaged" player is one who has a narrower range of possible reservation values compared to that of his co-bargainer. The degree of the advantage (>1.0) or disadvantage (<1.0) is measured by the ratio of the range of a player's distribution to that of his opponent's distribution range— for the buyer, G/F; for the seller, F/G.
[7] Such as deriving a probability distribution over a co-bargainer's actions, updating these beliefs in a Bayesian or non-Bayesian fashion, or maximizing payoffs given these beliefs.
[8] The Law of Effect states that decisions leading to positive outcomes are more likely to be taken in the future and those with negative outcomes suppressed.

Practice[9] (Blackburn, 1936). The DSR model performed remarkably well accounting for most of the variability of the data.

The same authors in a subsequent paper (RDS, 1998) continued their investigation into critical aspects of the bargaining mechanism primarily focused on the asymmetry between prior distributions of the buyer and seller. RDS noted that RS originally found that sellers more closely approximated the behavior posited by the LES than did the buyers. Consequently, the sellers earned more than expected under both truth-telling and LES models. Yet, DSR reported just the opposite result where the buyers earned more. The major difference between the studies was the information disparity between the player types. Support for the uniform priors in RS was symmetric whereas DSR used asymmetric but overlapping priors favoring the buyer. To test the information disparity hypothesis, RDS proposed two conditions -- one favoring the buyer (Condition BA) and the other favoring the seller (Condition SA). Condition BA replicated DSR Experiment 1 (the Baseline) except that it fixed trading pairs of buyers and sellers throughout the duration of the fifty-trial experiment. Condition SA was identical to Condition BA except that it favored the sellers in terms of information disparity. The information disparity framework used asymmetric priors of F~uniform[0,100] and G~uniform[0,200] for Condition BA and F~uniform[0,200] and G~uniform[100,200] for Condition SA. The motivation for fixed-pairing as opposed to the previously modeled random-pairing was to determine whether reputation effects enhance the advantage of the information disparity. The results showed that the information-advantaged player developed a reputation of aggressive bidding and effectively

[9] The Power Law of Practice states that the impact of consequences from early decisions is greater than the consequences of later decisions.

used it to further enhance his earned portion of the surplus at the expense of his opponent (seller). Comparing Condition BA to Condition SA, RDS showed that the effect was a result of the information advantage induced by the prior distributions and not the player role (buyer or seller). Whenever there was an information disparity favoring one of the bargainers, regardless of role, that player effectively used it to increase her relative share of the realized gains from trade.

Expanding on the DSR departure from previous studies focusing on the dynamic changes in trial-to-trial behavior, RDS also built on the success of their reinforcement-based adaptive learning model proposing several modifications: the RDS revised four-parameter model performed better than their previous (DSR) adaptive learning model and quite well prima facie accounting for most of the trial-to-trial variability of both buyers and sellers. More importantly, by testing their model on data gathered through a different experimental design (fixed versus random pairing), RDS provided further support for the generalizability of their learning model. Despite the differences between fixed and random designs, the RDS reinforcement-based adaptive learning model did as least as well as the DSR model of capturing changes in players' decisions through variation of the model's parameters.

The most recent experimental study relevant to the bargaining mechanism under consideration in the extant literature is a third paper by Rapoport and colleagues (SDR, 2001). SDR extended the inquiry of RDS into information effects by drastically increasing the disparity resulting in more divergent and distinctly prominent LES functions. Following from the results of their previous two studies, SDR focused their efforts on identifying the principal factors governing the realized gain from trade attained by each player type. To provide a more thorough test of the DSR information disparity hypothesis, SDR conducted

two more experiments investigating the level of the information disparity and player type effects. SDR Experiment 1 consisted of two conditions: Condition SA and Condition SLA. In Condition SA (seller advantage), SDR used the same distributions reported in RDS and DSR with F~uniform[0,200] and G~uniform[100,200]. In Condition SLA, the seller had a considerably larger advantage with distributions of F~uniform[0,200] and G~uniform[180,200]. SDR Experiment 2 (Condition BAC) yielded the advantage to the buyer with distributions of F~uniform[0,100] and G~uniform[0,200]. However, this experiment differed in that the buyers were unaware that they were not matched with a human seller. Instead, computerized robots programmed to play the LES simulated the sellers. This modification was necessary to ascertain whether the buyer's bids would be moderated when the seller was no longer willing to be "pushed down." Studying the dynamics of play was the second main focus of SDR. Using a revised version of the reinforcement-based adaptive learning model proposed by RDS, SDR sought to test the robustness of the RDS model on a set of data from a different experimental design.

The results of SDR Experiment 1 showed that the information disparity effect was indeed general: the information-advantaged player, regardless whether a buyer or seller, gained significantly higher profits from trade than predicted by the LES. Additionally, SDR Experiment 2 results illustrated that information-disadvantaged players can overcome the disparity by bidding more aggressively. In Condition BAC, sellers had the same priors as DSR Experiment 1. However, with the programmed sellers asking strictly in accordance with the LES, the sellers were able to prevent the excess surplus from going to the buyers.[10]

[10] Nine of the ten buyers retreated in the face of higher asking prices by the programmed sellers.

Finally, the results of the learning model from SDR successfully accounted for most of the trial-to-trial variability of the individual decisions.

A related experimental paper[11] that touches the bargaining literature via the negotiation literature is worthy of brief mention (VMB, 1998). Although important in its own right, the aim of the study stands in stark contrast to all previous studies in both its objective, methodological approach, and experimental design, and yielded no meaningful implications for the studies reported in this dissertation for a variety of reasons. First, the role of communication and the effects of various media was the primary focus of the paper with the main result that face-to-face communication improved the efficiency of the mechanism (qualitatively assessed). Second, the authors did not consider whether or not subject behavior approximated any particular equilibrium but instead made only relative comparisons between treatments. Third, the experimental design differed considerably from previous studies in the literature. In some cases subjects were paid while in others they were not. In one study, subjects knew one another well while in another the subjects were total strangers. And in all treatments, subjects only engaged in a single-play of the game and thus were never afforded any opportunity for learning. Therefore, for the noted reasons, results of this study as well as other studies from the negotiation literature are not considered further.

[11] Although the VMB findings are interesting in their own right, they are not at all informative of equilibrium play, a fundamental aim of this manuscript.

C. METHODOLOGY

A primary consideration in the chosen method of investigation is how to control incentives. In order to collect meaningful data, it is imperative that participants are properly motivated as to reliably elicit preferences consistent with utility theory. To accomplish this and in accordance with the generally accepted norm in experimental economics, all subjects in all reported studies were paid a show-up fee with additional earnings contingent upon performance. The theoretical justification for using money as an incentive is not entirely clear since the association between utility and money is completely ad hoc (Luce and Raiffa, 1957, p. 20). However, because observed behavior for the preference of money is relatively consistent with utility theory (i.e. more is better than less, linearity) and because the fungibility of money generalizes the preference for it (i.e., the utility for money), subject payment has become the standard method of motivating behavior. There is no reason to suspect that paying subjects would result in *lesser* quality data (Parco, Rapoport, and Stein, in press).

The method used to recruit subjects is another key consideration in the design of experimental research. Ideally, if the principal objective were to generalize experimental results beyond the laboratory to a given population, then randomly selecting subjects from the general population would best achieve parallelism. However, limited experimental budgets and geographic constraints normally render such a procedure unrealistic. The most common procedure used in behavioral decision-making research is to recruit from the undergraduate student population at the university where the experiments are conducted. This common practice often raises concerns that results may not be generalizable "beyond

college sophomores." However, because the predominant theories are normally general in nature and not qualified as to whom the theory should apply and to whom it should not, the counter-argument in favor of local recruiting methods is that any reasonably competent, willing volunteer should suffice taking advantage of whatever sample diversity is available. The primary population from which subjects were recruited for the reported studies was the local student body. However, there were also additional opportunities to collect data on more sophisticated subjects through summer workshops hosted by the Economic Science Laboratory as reported in Chapters IV and V.

Although the focus of the following studies is on individual behavior, the unit of analysis is the group since choices are not independent in a single-shot recurring-trial interactive decision-making context. Replication of the experiments is therefore required to ensure that findings are verifiable and not a result of chance relationships. Following the procedures laid out in DSR Experiment 1, a similar general experimental design has been implemented in all three studies to facilitate comparisons between experiments. Specifically, each session consisted of twenty subjects: ten buyers and ten sellers. All subject volunteers were recruited and used in accordance with Human Subjects' Committee guidance and paid a $5.00 show-up fee,[12] regardless of whether or not they participated as subjects in the experiment. Once recruits arrived at the experiment location but before each was seated, everyone was given the opportunity to leave (and a few actually did). Participants were promised to be paid contingent on their performance, noting that in this interactive decision-

[12] And in some cases, extra credit for courses requiring participation but completely unrelated to the studies themselves (see Appendix K, page 249, for Human Subjects Committee approval documentation.)

making task, payoffs were determined by the interaction of the bargainer and co-bargainer decision.

Each session lasted approximately one to two hours.[13] Subjects were given the printed instructions and allowed to read them during the first fifteen minutes of the session (see Appendices B through J). Two laboratories were used to conduct the experiments: the Economic Science Lab (ESL) and the Enterprise Room (ER), both located at The University of Arizona. The ESL is comprised of forty networked computers each enclosed in a private cubicle. The ER is smaller, containing only twenty-four workstations in a large open room with computer terminals well separated from one another to prevent communication between the subjects. For the sessions conducted in the ER, buyers were seated on one side of the laboratory and sellers on the other to help prevent any transfer of private information between trader types. Upon entering the laboratory, participants were randomly assigned a seat and informed that they would engage in a series of independent games with their co-bargaining partners randomly varied from trial to trial. To facilitate direct comparisons between sessions, identical random reservation values were used for each session within a particular experiment. However, to facilitate between-subjects comparisons, each player received a different permutation of the same reservation values. Each session was structured in exactly the same way and iterated for fifty trials to ensure sufficient data to accommodate learning analysis.

<u>(1) Procedure</u>. At the beginning of each trial, both seller and buyer jointly received information regarding the prior probability distributions from which their own values would

[13] Two and a half hours for subjects in the two-stage mechanism's Sophisticated condition – see Chapter IV.

be drawn as well as the distribution from which their co-bargainer's value would be drawn. This was common knowledge. Each player also independently received a private reservation value randomly drawn with equal probability from his or her respective distribution. Bargaining commenced via computer messages with buyer (seller) being prompted to state her offer to buy (offer to sell) for the trial. The computer required the subjects to confirm their responses and warned them if their offer <u>could</u> result in a loss (i.e., if $s < v_s$ or $b > v_b$). Sellers were unconstrained as to the value they could ask in the experiments in excess of zero, but buyers were prevented from making any offer in excess of β_b, the upper limit of G. Prior to entering their responses, the subjects were allowed to review their previous responses and outcomes by calling up a separate screen. After all twenty subjects responded, the monitoring computer determined for each pair separately whether a deal was struck, and calculated the payoff for each (either v_b - p or 0 for the buyer, and either p – v_s or 0 for the seller). Subjects were then informed of their decision, their opponent's decision, and if an agreement was reached. If so, then the trade price, p, was also reported. Each player also was privately shown his results (gain or loss) from the trial. Subjects were allowed to proceed at their own pace within each trial. However, because players were randomly rematched between trials, it was necessary for all players to complete each trial before the experimental session advanced to the next trial. Once all trials were completed, each subject was separately and privately paid contingent on his or her performance, thanked, and dismissed.

<u>(2) Other General Considerations</u>. The process of matching subjects for the studies posed an important methodological issue: fixed or random pairing. Given that every

experiment included fifty trials, reputation effects could have had a significant impact on the results as previously noted by RDS in their replication of SDR's Experiment 1 using fixed rather than random matching. Truth-telling, although Pareto optimal, is a dominated strategy for most of the games under study.[14] However, with fixed-pairs over fifty trials, it is quite possible that paired subjects would evolve to a Pareto optimal strategy as has been demonstrated in repeated play prisoners' dilemma games (Rapoport & Chammah, 1965). Because of the focus of the proposed studies on a static assessment of efficiency, it was necessary to employ the random-matching design for all experiments (see RF and RDS for discussion).[15]

D. Introduction of Experiments

(1) Baseline Study. The primary objective of this dissertation is to evaluate manipulations of the standard two-person, single-stage, sealed-bid *k*-double auction mechanism using a midpoint trading rule to determine the effects on the *ex post* efficiency. Although considerable theoretical and experimental work has been done on this particular mechanism, replication of a previous single-stage study is necessary to not only determine whether or not the method and experimental design generate any significant differences in behavior beyond what is already known in the extant literature, but also to form a standard of comparison for the studies reported here. The Baseline Condition experiment, a replication of DSR Experiment 1, is discussed in Chapter II and referred to as a control group throughout Chapters III-VI.

[14] Full and Reframed Full Bonus conditions of Chapter III are the exception.
[15] With ten buyers and ten sellers, each trader encountered the same co-trader about five times during each session.

(2) Bonus Mechanism. The (theoretical) source for inefficiency in bargaining under incomplete information is due to a player's incentive not to reveal his true reservation value. Consequently, bargainers sometimes fail to achieve mutually profitable agreements. In order to make truth-telling a dominant, incentive compatible Pareto efficient strategy "it is necessary to incorporate a third party into the game so that a grand coalition can form" (Brams, 1990). To achieve the effect of a third party while preserving the bilateral structure of the game, the third party will be simulated by introducing a bonus into the payoff function of each bargainer if an agreement is reached. Brams and Kilgour (1996) proposed several alternative procedures for modifying the payoffs of both traders so that complete disclosure of one's reservation value becomes a weakly dominant strategy, thus avoiding inefficient outcomes. Chapter III reports on one of these procedures, specifically the "Bonus Procedure."

(3) Two-stage Mechanism. Extending the bargaining period from a single-stage game to a multi-stage game is a natural progression of the existing research. With additional periods of bargaining, each player has an opportunity to reveal information about his reservation value in order to coordinate his behavior with his co-bargainer and improve the likelihood of capturing available gains from trade. By incorporating an additional costless round of bargaining, players have an opportunity to pursue a strategy or revealing information in an attempt to coordinate decisions in the direction of the Pareto optimal, truth-telling strategy resulting in increased mechanism efficiency over a similar single-stage games. However, players can also posture and bid too aggressively during stage 1 yielding no information relegating the two-stage game to a single-stage game. Chapter IV reports

results from a two-stage game played with groups of inexperienced, experienced, and sophisticated players.

(4) Varying-k Mechanism. The experiments discussed in Chapters II, III and IV as well as all previous experimental work on the sealed-bid mechanism employed the midpoint rule (k=½) resulting in a price halfway between the buyer's bid and the seller's ask. To recapitulate, under the k-double auction mechanism, simultaneously the seller submits an ask, $s=S(v_s)$ and the buyer submits a bid, $b=B(v_b)$. Trade occurs at price $p=kb+(1-k)s$, if and only if $b \geq s$. If, instead k=0, the seller sets the price unilaterally. Conversely, if k=1, the buyer sets the price unilaterally. Values of k which diverge from k=½ yield more "power" to one of the bargainers when F and G are distributed identically and symmetrically[16] (CS, 1983). With rare exception,[17] the experimental research on bilateral bargaining games under incomplete information has relied on designs which have exclusively set the trading parameter to k=½. This is in stark contrast, however, with traditional real-world application of the sealed-bid mechanism, which more often employs an extreme value of k with one of the bargaining parties determining the trade price by being the highest (or lowest) bidder (e.g. federal procurement). Theoretical analysis suggests that expected profit of a seller (buyer) is decreasing (increasing) in k. But the literature is silent on ex post efficiency for values of k other than ½. Chapter V reports the results of four experiments with extreme values of k in two asymmetric information environments.

[16] Qualified to symmetric common priors as not to confound "power" over trade price with "power" of an information advantage – the focus of Chapter V.
[17] RS Experiment 4 set k=1.

E. INTEGRATION OF THE EXPERIMENTS THROUGH LEARNING MODELS

While the experiments in Chapters II, III, IV and V all address variations of the same bargaining mechanism, the optimal strategies theoretically suggested by the LES differ widely. In many cases, observed behavior of individuals closely approximates the LES. But because subject participants do not have the time, and in most cases, the computational capacity to solve for the optimal strategies in the experimental setting, in other cases behavior is quite divergent. Paramount to understanding individual differences in behavior relies on modeling the convergence properties.

By definition, the LES is the unique Bayesian-Nash equilibrium in piece-wise linear strategies. In equilibrium, neither player can benefit from unilateral deviation (Nash, 1951). If, however, a player does deviate (to her detriment), then her co-bargainer's best reply is no longer the original LES. Given bilateral deviation from the LES, Bayesian-Nash concepts are elusive as a static model. In a single-shot game, no opportunity is available for learning and the optimal strategy is always the Bayesian-Nash equilibrium. However, when subjects engage in multiple trials of the same game, they have opportunities to adapt their behavior to optimize their strategies, given their environments. If players cannot identify the equilibrium by introspection, then they may reach it by some adaptive process. In a way, multiple iterations give a chance to the single-stage equilibrium to emerge through some learning process. Thus, an optimal strategy is not necessarily one predicted by theory, but rather one that can adapt and flourish in its environment comprised of the population of players. To account for the dynamics of learning, focus must be on individual subjects and not the population. Although the populations may demonstrate group behavior that illustrates

learning, it is the individuals who are learning and not the group. Learning occurs differently for different people in different environments. Therefore, a viable learning model must robustly account for individual differences in different tasks.

To capture the learning effects of the reported experiments, following the approach laid out by RDS, Chapter VI discusses results of their reinforcement-based adaptive learning model aimed at capturing the learning process of individual subjects across experiments to account for the dynamic process of trial-to-trial variability. The power of this particular learning model lies in both its parsimony and simplicity making minimal demands on the rationality and reasoning ability of the players. The model presumes that players remember what strategies worked well and what ones worked poorly on previous trials. The comparison of parameters between experiments in Chapter VI illustrates the common thread across the bargaining tasks yielding a general understanding of the bargaining mechanisms under conditions of incomplete and asymmetric information. Chapter VII summarizes and concludes.

CHAPTER II: BASELINE STUDY

A. INTRODUCTION

All too often in social science, important experimental results are not independently replicated as a result of perverse incentives to do so. Journals are usually unwilling to allocate scarce pages to reaffirm that which is already known forcing researchers to effectively take as given published results and move forward. However, our knowledge base depends on assimilating facts that generalize across researchers, subject populations and methodologies. Despite the considerable experimental evidence amassed on the sealed-bid *k*-double auction mechanism, replicating previous studies serves not only to reaffirm that which is already known, but also to act as a conduit between the extant literature and the evidence generated from this manuscript.

DSR took a replication approach by modeling their Experiment 1 after RF's Experiment 2. However, the DSR replication was not exact as it also increased the number of trials from thirty to fifty, implemented a computerized program to collect data versus the hand-run method of RF, and provided subjects a complete history of results of their previous decisions. DSR chose to build upon the RF experiment because the information asymmetry induced a piece-wise linear bid function for the information-advantaged player and provided a more stringent test of the LES. This dissertation builds upon this particular case by first directly replicating DSR Experiment 1 in all of its detail. To foster more direct comparison between the studies, identical matching protocol and random valuation draws are implemented to minimize the unsystematic variance. In doing so, the manipulations in

Chapters III-V can ascertain real effects based on this replication study as a standard of comparison.

B. THEORY

The original LES formulation published by CS contained several typographical errors, which have been verified (Parco and Stein, 2001) and correctly annotated below for any pair of prior probability distributions where F~uniform[α_s, β_s] and G~uniform[α_b, β_b]:

$$S^*(v_s) = \frac{\alpha_b - s_0}{1+k} + s_0, \qquad \text{if } \alpha_s \le v_s < \frac{2-k}{1+k}(\max(s_0,\alpha_b) - s_0) + \alpha_s \tag{2.1}$$

$$S^*(v_s) = \frac{v_s - \alpha_s}{2-k} + s_0, \qquad \text{if } \frac{2-k}{1+k}(\max(s_0,\alpha_b) - s_0) + \alpha_s \le v_s \le \min(s_1, \beta_s) \tag{2.2}$$

$$B^*(v_b) = \frac{v_b - s_0}{1+k} + s_0, \qquad \text{if } \max(s_0,\alpha_b) \le v_b \le \frac{1+k}{2-k}(\min(s_1,\beta_s) - \alpha_s) + s_0 \tag{2.3}$$

$$B^*(v_b) = \frac{\beta_s - \alpha_s}{2-k} + s_0, \qquad \text{if } \frac{1+k}{2-k}(\min(s_1,\beta_s) - \alpha_s) + s_0 < v_b \le \beta_b \tag{2.4}$$

where $s_0 = [(1+k)\alpha_s + (1-k)\beta_b]/2$ and $s_1 = [k\alpha_s + (2-k)\beta_b]/2 = s_0 + (\beta - \alpha)/2$.

These results not only recapitulate the original CS formulation but also extend their Theorem 3 for any pair of uniform overlapping priors.

Two assumptions are worthy of mention to facilitate later analysis of the bargaining game. The first assumption requires, for any pair of equilibrium strategies, that *no other* pair of strategies give both players at least as great ex ante gains. Likewise, no other pair of strategies would yield a larger payoff to one of the players (Linhart et al., 1992). In short, ex ante efficiency <u>requires</u> that any equilibrium pair of strategies be a Nash equilibrium. The second assumption requires "interim individual rationality" (Myerson and Satterthwaite,

1983). Because bargaining is a voluntary activity, it is assumed that each player will want to participate in advance of knowing his reservation value for the trial regardless of what his reservation value turns out to be if and only if $v_b \geq b$ or $v_s \leq s$. A player following this assumption can ensure himself a nonnegative outcome and would be described as *interim individually rational*. For any game of two-sided incomplete information, the equilibrium allocations cannot be efficient if a player, after being informed of his reservation value but prior to making an offer, has a nonnegative expected gain for each possible reservation value. Thus, if the assumption of interim individual rationality holds, regardless of a player's reservation value, he will choose to participate in the bargaining game since he can guarantee himself interim individual rationality by ensuring $v_b \geq b$ or $v_s \leq s$.

The parameters of the game that form a standard of comparison for the following studies reported in this manuscript are as follows.[18] Asymmetric (uniform) common priors yield the buyer an information advantage with F~uniform[0,100] and G~uniform[0,200].[19] The trading parameter is set to $k = ½$ retaining the fairness norm inherent in most of the previous studies. Computing the LES for the baseline game yields the results depicted in Figure 2-1. For the seller, the optimal strategy ($S^*(v_s)$) is to ask 50 for a reservation value of zero and then increase her ask by $2/3$ for each unit increase in the reservation value. For her upper-most reservation value at β_s =100, she should ask s=116.67. This strategy is simply a linear function with a y-intercept of 50 and a slope of 0.667. For the buyer, the optimal strategy ($B^*(v_b)$) is slightly more complex. For reservation values between zero and 50, the

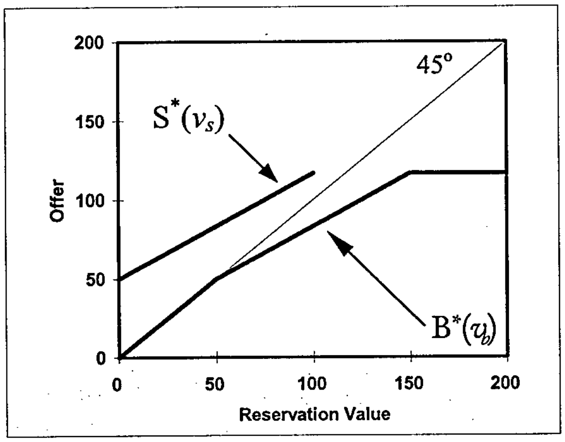
[18] The studies of Chapter V test the sensitivity by varying F, G, k and player role.
[19] The information advantage/disadvantage (see Footnote 6, page 31) is applicable only to uniform priors. This definition will not easily generalize to non-uniform priors.

buyer should bid truthfully ($b=v_b$). For each unit increase in reservation values above 50, the buyer should increase his bid by $2/3$ up to a maximum of b=116.67 for a reservation value of v_b =150. For all reservation values above 150, the buyer should bid b=116.67.

FIGURE 2-1. Linear Equilibrium Strategies, Two-Person Bargaining, $k = ½$

$$b = B^*(v_b) = \begin{cases} v_b & \text{if } v_b \le 50 \\ 50/3 + 2/3\, v_b & \text{if } 50 < v_b < 150 \\ 350/3 & \text{if } v_b \ge 150 \end{cases}$$

$$s = S^*(v_s) = 50 + 2/3\, v_s \qquad \forall\ v_s$$



Simple linear regression (ordinary least squares, or OLS) will be used to estimate the slope and intercept for the sellers' ask functions in order to make direct comparisons with the equilibrium. For the buyers, spline models will be fit to each buyer's data estimating slopes separately for the three ranges of reservation values: 0-50, 50-150, and 150-200. The spine regression technique finds the piece-wise linear function of best fit (also using OLS) by manipulating the three slopes while simultaneously adjusting the conjoining points of the line segments vertically along the theoretically predicted hinge points (v_b=50 and v_b=150). The spline functions can then be compared directly to the LES. In cases of asymmetry in the supports of the uniform reservation value distributions, the information-advantaged player will always have a piece-wise LES function, regardless whether the player is a buyer or seller.

C. METHOD

(1) Subjects. The Baseline game data set was generated by two sessions of undergraduate students enrolled in a bargaining course during the first day of classes, prior to the students meeting the instructor or receiving a copy of the syllabus.[20] Forty students participated for course credit in lieu of $5.00 show up fee but were paid contingent upon their performance in the experiment consistent with standard procedures. Each session lasted approximately one hour. Mean earnings for the sessions were $12.93 and $12.44 with payoffs ranging from $8.38 to $18.03.

(2) Procedure. One session was conducted in the Enterprise Room (ER) and the other session in the Economics Science Laboratory (ESL) at the University of Arizona. Subjects were required to participate to fulfill course requirements and understood that their individual performance in the game would affect their course grade. Additionally, all participants were informed that they would also be paid their earnings from the experiment in cash immediately following the session. Once all participants had signed the consent forms, each drew a card numbered from one to twenty to identify their seat assignment in the lab. Subjects drawing cards numbered one through ten assumed the role of a buyer and the remaining subjects assumed the role of seller. Subjects read a written set of instructions at their own pace (see Appendix B). All of the buyers sat on one side of the laboratory and all of the sellers on the other to prevent any transfer of private information between buyers and sellers. The subjects were explicitly instructed that their bargaining partners were randomly varied from trial to trial. All fifty trials were

[20] This procedure was replicated during two successive years during the fall semester of classes.

structured in exactly the same way. At the beginning of each round each seller and each buyer privately received a reservation value randomly drawn with equal probability from their respective distributions. To allow between-subjects comparisons, each trader received a different permutation of the same 50 reservation values.

Bargaining continued with buyer (seller) being prompted to state her offer to buy (offer to sell) for the trial. The computer required the subjects to confirm their responses and warned them if they might lead to a loss (i.e., if $s < v_s$ or $b > v_b$). Prior to confirming their responses, each subject could review his previous responses and outcomes by calling up a separate screen. After all twenty subjects responded, the monitoring computer determined for each pair separately whether an agreement was reached and calculated the payoff for each (either v_b - p or 0 for the buyer, and either p - v_s or 0 for the seller). Subjects were then informed of their decision, their co-bargainer's decision, and if an agreement had been reached, the trade price p and the gain for the trial. Due to the recurring single-play random-matching design, the slowest player dictated the experiment pace. Once all fifty trials were completed, each subject was separately paid contingent on his performance and dismissed.

D. Results

(1) Comparison with Previous Studies: DSR Experiment 1.[21] The present study serves as a conduit between previously published experimental research on the bilateral bargaining mechanism under two-sided uncertainty and the extensions investigated in Chapters III-V. The Baseline experiment replicates Experiment 1 of DSR (1998). Comparisons using number of deals, deviations from equilibrium, or achieved surplus

[21] Special thanks to Darryl A. Seale for supplying the original data from DSR Experiment 1.

yielded no differences between sessions of the present study. Despite the more aggressive behavior of information-advantaged buyers in the first session, there are no significant differences between groups with respect to either buyer behavior (t=1.23, p=0.23) or seller behavior (t=0.55, p=0.608). Similar comparisons with DSR Experiment 1 also reveal no differences at α=0.05 (t<1.72 and p=0.112). See Tables 2-1 and 2-2 for coefficient comparisons.

(2) Individual Data.

(a) Baseline Condition, Buyers. Variation in subject behavior necessitates inspection of individual data before drawing conclusions from the aggregate data. Although aggregate results are useful in statistically identifying variation in behavior beyond that of chance, the variability both within and between subjects provides insight into types and methods of learning. Turning first to Figure 2-2a which plots individual decisions of the buyers in both groups (Subjects 1-20) in the Baseline Condition, one can identify considerable variability in bidding behavior. Reservation values (v_b) are plotted along the horizontal axis and observed bids, b, are plotted on the vertical axis. A diagonal line represents truthful revelation of reservation value while the piece-wise function identifies the LES for F~uniform[0,100] and G~uniform[0,200]. This particular equilibrium forms the baseline for comparison. In the Baseline Condition, theory predicts that the data should lie along the LES function. With few exceptions, the preponderance of bids lie on or below the LES (Figure 2-2a). This observed more-aggressive-than-predicted behavior is consistent with the information disparity hypothesis which proposes that the information advantaged player will extract a disproportionately favorable share of the gains from trade at the expense

FIGURE 2-2a, Baseline, Buyers

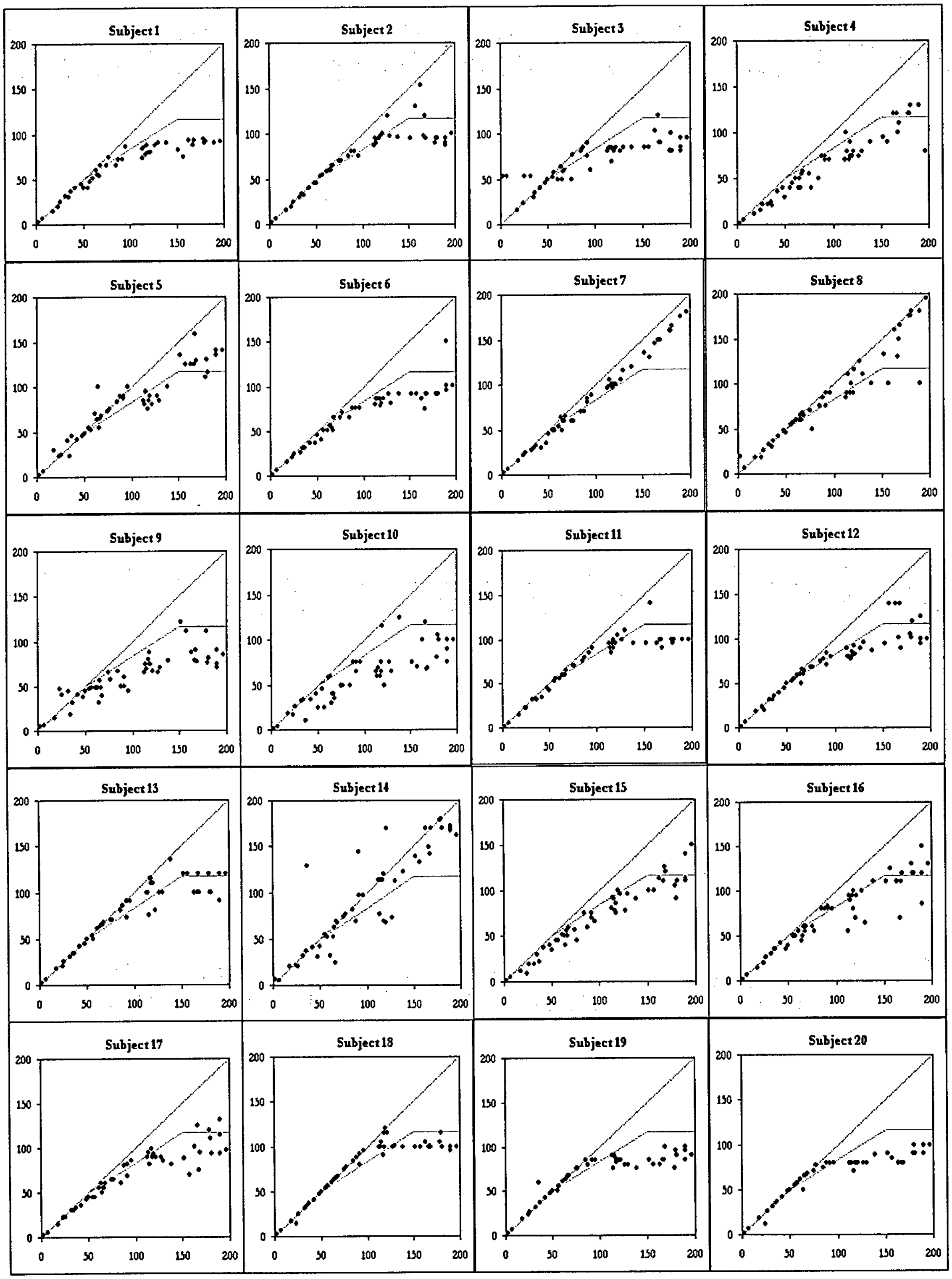
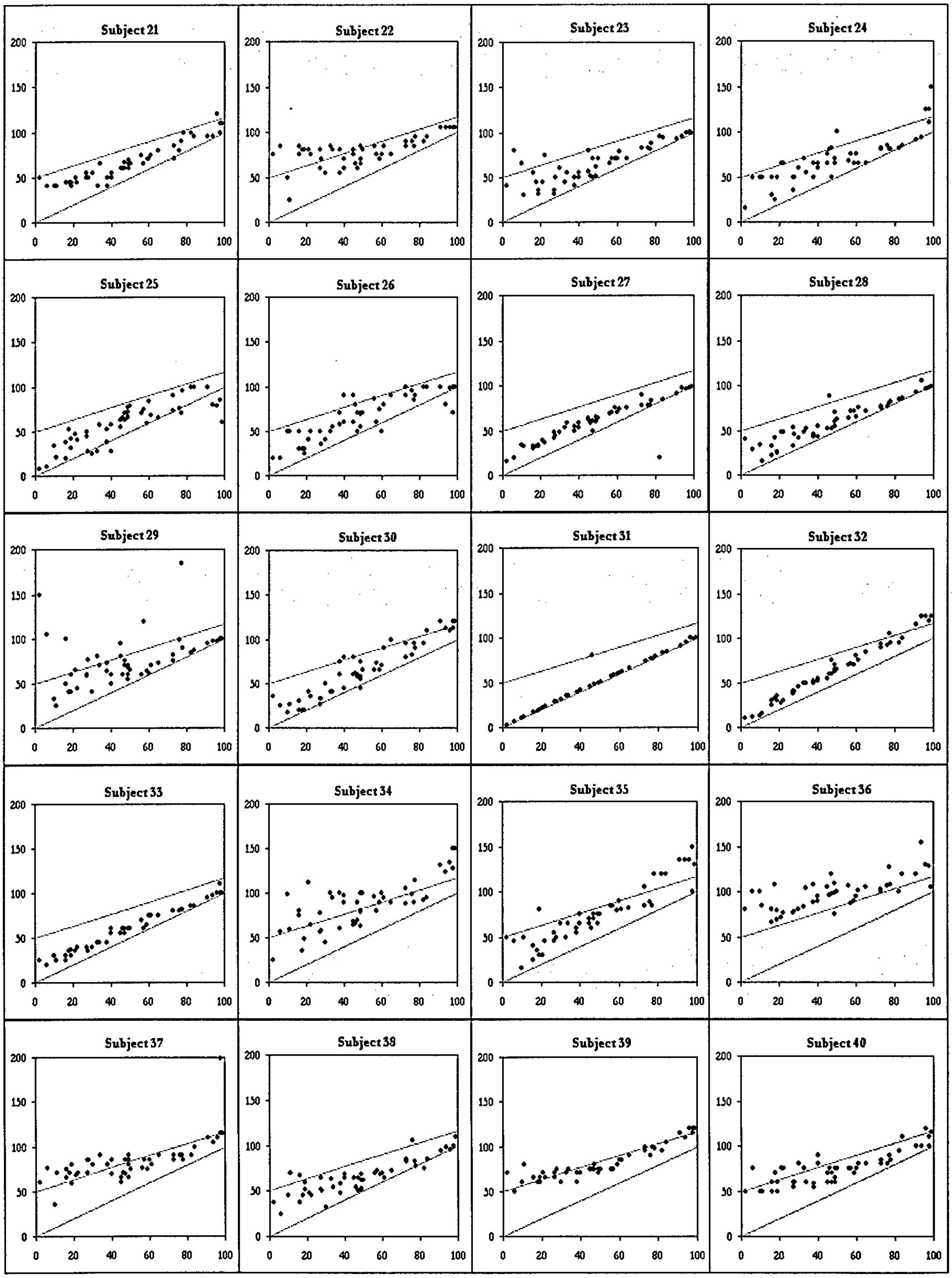


FIGURE 2-2b. Baseline, Sellers



of the opposing party (DSR, 1998). Note that both Subjecst 7 and 8 pursue more truthfully revealing strategies to their detriment. Aside from Subjects 3 and 14 who made several offers where $b > v_b$ incurring losses on some of the trials, Subjects 7 and 8 consequently earned less than all of the other subjects (which is expected since truthful revelation is a strictly dominated strategy). Subject 3 submitted four bids where $b > v_b$. These offers occurred between Trials 13 and 17 for low values of v_b. Upon realizing a negative payoff, the $b > v_b$ behavior ceased for Subject 3. Similarly, Subject 5 $b > v_b$ behavior occurred through Trial 23 with the first and only realization of negative earnings occurring on Trial 21. In both cases, the decisions to bid more than valuation appears to be deliberate. As for Subject 14, making sense of the $b > v_b$ behavior which occurred three times (Trials 6, 20 and 42) is less clear. Common to all of the buyers is the predicted "shaving" ($b < v_b$) differing only in the extent of shaving for various reservation value levels.

<u>(b) Baseline Condition, Sellers.</u> Baseline sellers (Figure 2-2b) showed no evidence of pursuing truthfully revealing strategies. Similarly to the buyer plots, the vertical axis represents s and the horizontal axis, v_s. The lower line identifies the truth-telling function and the upper line the LES function for the fixed F and G. As with the buyers, shaving is evident with each seller. Also consistent with the information disparity hypothesis, the sellers as the disadvantaged players are less aggressive than theory predicts and consequently yield more of the surplus to the buyers. Although both Subjects 22 and 29 demonstrated the most aggressive behavior, they along with the other subjects made most of their decisions between the lower and upper lines on the plots. In several cases, Subjects 25, 26 and 27 demonstrated offers where $s < v_s$. However, all data points have been retained in the data set for analysis.

(3) Aggregate Analysis. Table 2-1 reports the regression results of the buyers in two blocks (25 trials each) separately and across all 50 trials. Slopes were estimated separately for the three ranges of reservation values: (1) $v_b<0$; (2) $50\leq v_b\leq 150$; and, (3) $v_b>150$. Consistent with previous studies, the buyers are more aggressive than predicted by the LES given their superior information advantage. Both the slopes and intercepts moved in the direction of the LES during the course of play as evidenced in the change in coefficients between blocks. Behavior was still more aggressive than predicted, but less so over time. The regression models yield $R^2 \geq 0.75$ indicating a very good fit, soundly rejecting a truthful revelation model.

Observed behavior of the sellers was also very similar to that of previous studies as shown in Table 2-2. Because of their information disadvantage, sellers were less aggressive than predicted by the LES yielding an intercept of 32 (instead of 50). Over the course of repeated trials, the intercept moved in the direction of the LES, but not to the extent predicted. The slope of the regression function came within 0.07 of the LES and decreased to within 0.03 during the second block. During the first block of play, R^2=0.60 but fell to

TABLE 2-1. Spline Regression Results, Buyers by Block

	$v_b < 50$		$50 \leq v_b \leq 150$		$150 < v_b$		
	Slope	Intercept	Slope	Spline knot	Slope	Spline knot	Adj. R^2
LES	1.00	0.0	0.67	50.0	0.00	116.7	
Trials 1-25	0.90**	2.7	0.57**	47.9	0.25*	104.6	0.75
Trials 26-50	1.01**	-1.2	0.60**	49.3	0.09**	109.0	0.77
Across trials	0.96**	1.0	0.58	48.8	0.17**	106.6	0.76
DSR Experiment 1	0.88	*Not reported*	0.61	--	0.16	--	0.87

*p <0.01 and **p <0.001 testing whether the coefficient is significantly different than zero

only 0.20 during the second block. Inspection of the individual data reveals increasing individual differences as sellers gained experience with the game. Some sellers became increasingly aggressive not wanting to be "pushed down" by the buyers while other sellers, to a lesser extent, backed down and yielded to the aggressive buyer bids.

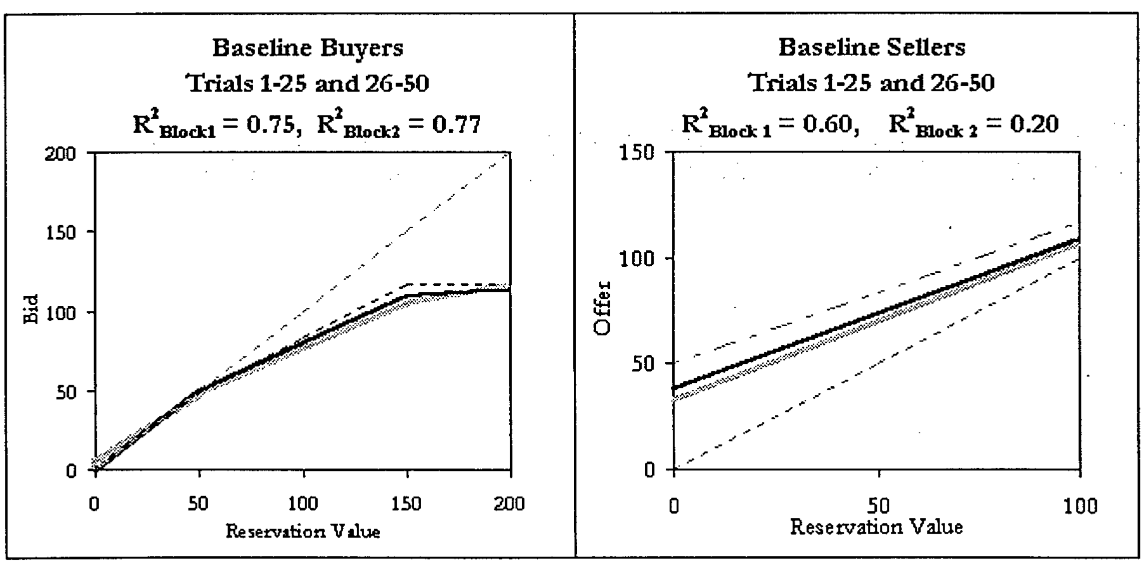
TABLE 2-2. Regression Results, Sellers by Block

	Slope	Intercept	R^2
LES	0.67	50.0	
Trials 1-25	0.74	32.6	0.60
Trials 26-50	0.70	38.0	0.20
Across trials	0.72	35.2	0.32
DSR Exp.1	0.73	39	0.67

Note: All reported statistics are significantly different than zero at $p<0.001$, $\alpha=0.05$

Figure 2-3 illustrates the regression functions by block (gray lines represent the first block and solid black lines the second.) Although there is very little difference between the functions by blocks, the noteworthy observation is that over the course of play, both buyer and seller functions move in the direction of the LES.

FIGURE 2-3. Best-fitting OLS Regression Functions by Block



(4) Baseline Discussion. Several conclusions can be drawn from this replication study highlighting the findings of DSR (1998):

- These results replicate earlier findings of DSR.
- The Truthful Revelation Model can be rejected as players largely bid in accordance with the LES, consistent with earlier findings.
- The information-advantaged players effectively use their advantage to unilaterally achieve a greater portion of the surplus than predicted by the LES.
- Over time, both buyer and seller offers move in the direction of the equilibrium.

Thus, it is reasonable to conclude that the approach and methodology for this and subsequent studies of this dissertation are consistent with that of previous studies. This Baseline condition shall, therefore, be the standard of performance for a single-stage two-person bargaining game of incomplete information to which subsequent chapters will refer.

CHAPTER III: BONUS MECHANISM

A. INTRODUCTION

Vickery (1961) showed the fundamental impossibility of designing a bargaining mechanism in such a way that (1) honest revelation is a dominant strategy for all players; (2) no outside subsidy is needed; and (3) the final allocation of goods is always Pareto-efficient ex post. Myerson and Satterthwaite (1983) further showed the general impossibility of ex post efficiency in bilateral bargaining games of incomplete information without external subsidies. Although previous experimental studies have substantiated both Vickery and Myerson and Satterthwaite's theorems regarding the impossibility of achieving *perfect* ex post Pareto efficiency, there has been little exploration into efficiency *improvements* of the bargaining mechanism under incomplete information. Subsequent theoretical analyses (Brams and Kilgour, 1996; hereafter BK) suggest that some procedures can be devised to improve bargaining efficiency by inducing individuals to truthfully reveal their respective values.

<u>(1) Theoretical Solution</u>. BK (1990) proposed several changes to the bargaining mechanism that theoretically achieve ex post efficiency. By assessing penalties or providing bonuses to both parties as a punishment or reward for coming to a deal, the BK refinements induce a unique dominant strategy of truthful revelation of value, or "honest bidding" where $b=v_b$ and $s=v_s$. By incorporating a "bonus" for making a deal or a "penalty" for not making a deal, BK developed six separate procedures that induce honesty in the bargaining game. The Penalty Procedure, however, is not concerned with ex post efficiency, and in fact, is only 50% efficient (BK, 1990). Additionally, four of the BK procedures rely on an independent appraisal of the item being bargained over, which incorporates an additional dimension to

the game beyond the current scope of this chapter. Thus, this investigation will be strictly confined to the BK Bonus Procedure.

Although theories of coalition formation provide no insight into two-person games, in order to make truth-telling a dominant strategy and ensure incentive compatibility of the Pareto efficient strategy, it is necessary to incorporate a third party into the game so that a grand coalition can form (Brams, 1990). In order to achieve the effect of a third party while preserving the bilateral structure of the game, the third party can be simulated by introducing a "bonus" into the payoff function of each bargainer if a deal is reached. In the Bonus Procedure, a third party (a computer in this particular design) offers the buyer and seller a unique bonus in addition to the gains available for trade that renders complete disclosure of their reservation values a (weakly) dominant strategy. Specifically, each player receives an endogenous bonus when, and only when, an agreement is reached. This bonus must depend on the actual bid and ask, not necessarily on the reservation values that are private knowledge. Theorem 1 (BK, 1996) states that there exists exactly one bonus function satisfying these properties where the buyer's dominant strategy is to bid $b=v_b$ and the seller's dominant strategy is to offer $s=v_s$, if and only if, the bonus is calculated as $(b-s)/2$.

<u>(2) Limitations</u>. A fundamental limitation of the Bonus Procedure is that it is vulnerable to collusion (BK, 1996) if both players show maximum generosity to their co-bargainer. This is accomplished if the buyer bids $b=B(v_b)=\beta_b$ (the upper limit of G) and the seller asks $s=S(v_s)=\alpha_s$ (the lower limit of F) for all v_b and v_s. The size of the benefit for each player from tacit collusion strictly depends on F and G. Further, given the vulnerability of the collusion equilibrium to untrustworthy co-bargainers, collusion can probably be made

risky for the colluders if it cannot be ruled out altogether (BK, 1996). To reduce any further incentive for collusion, the experimental design implements random-matching of subjects to minimize the possibility of reputation effects.

(3) Overview of Bonus Study. In the absence of a bonus, the game reverts to the traditional bargaining mechanism which has been shown to support the LES (Rapoport and colleagues, 1995; 1998a; 1998b; 2001). The Baseline Condition presented in Chapter II (referred to in this chapter as the "No Bonus" condition) is necessary not only in order to provide an adequate test of the effects of incorporating the bonus component in the payoff functions, but also to establish a control group by which to measure these effects. It should be noted that previous studies have shown strong support for the "information disparity hypothesis" (see RDS and SDR). However, as the bonus is increased, truthful revelation becomes the (weakly) dominant strategy yielding a decreasing opportunity for the information-advantaged buyer to strategically influence the seller. Because of the asymmetry, the buyer can unilaterally suppress the seller's earnings by never bidding more than β_s (upper limit of F) $\forall$ $v_b \geq \beta_s$ when $\beta_b > \beta_s$. In fact, implementing a full bonus eliminates any benefit of an information-advantage to the buyer. The advantage is instead conveyed to the seller (the information-disadvantaged party) provided that the buyers bid honestly since each player's offer determines their co-bargainer's earnings given that a deal is made.

The three experiments introduced in this chapter ("Partial Bonus," "Full Bonus," and "Reframed Full Bonus") inquire into increasing levels of the bonus component and framing effects of the payoff function. The bonus is defined as $\theta(b-s)$. If $\theta = {}^1/_2$ (half of the difference of the offers), then theory predicts a bilateral weakly dominant strategy to bid

honestly. However, $\theta(b-s)$ could be set to any amount constrained by $0 \leq \theta \leq ½$ theoretically attenuating the strategic behavior in the direction of truth-telling. The Partial Bonus and Full Bonus conditions test the honesty hypothesis (see Appendix C and Appendix D for Partial Bonus and Full Bonus condition instructions). In the Partial Bonus condition, the bonus is set to the midpoint ($\theta = ¼$) between the No Bonus condition ($\theta = 0$) and the Full Bonus condition ($\theta = ½$) yielding $(b-s)/4$. If behavior is consistent with theory, results should illustrate behavior somewhere between truth-telling and LES strategic bidding. Ex post efficiency should also increase linearly in increasing values of the bonus function while remaining sub-optimal to the truth-telling equilibrium. In the Full Bonus condition, setting $\theta = ½$ provides a direct test of the BK theory. If the theory holds, ex post efficiency should be achieved. Note that it is possible in this condition for the ex post efficiency to exceed 1.0, meaning that deals occur despite that $v_s > v_b$. Such deals could be considered rational if players' jointly believed that the bonus amount would overcome any losses due to trade yielding nonnegative earnings. Thus, efficiency levels above 1.0 would provide direct support for the collusion equilibrium.

The Reframed Bonus condition is structurally identical to the Full Bonus condition. The only difference is in how information is presented to the subjects. In the Full Bonus condition, profit from each trial is presented in two separate components of trade price: (1) gains from trade; and, (2) gains from the bonus. The Reframed Full Bonus condition 'simplifies' the profit function by patently identifying to each player that his individual bid has no effect on his earnings, other than determining whether or not a deal is made (see Appendix E for the Reframed Full Bonus condition instructions).

B. THEORY

BK proved that for the Full Bonus condition, θ=½ uniquely yields truthful revelation as a weakly dominant strategy in the bargaining game. For the No Bonus condition, the utility maximizing strategy is the LES defined by equations (2.1) through (2.4) in Chapter II. However, for the Partial Bonus condition, the LES must be revised to account for the bonus, $\theta(b-s)$. Incorporating θ and redefining the constants s_0 as s_1 to τ_0 and τ_1, the LES generally solved for any value of $0<\theta<1$ is given by equations (3.1) through (3.4) below:

$$S^*(v_s)=\frac{\alpha_b-\tau_0}{1+k-\theta}+\tau_0, \qquad \text{if } \alpha_s\le v_s<\frac{2-k-\theta}{1+k-\theta}(\max(\tau_0,\alpha_b)-\tau_0)+\alpha_s \tag{3.1}$$

$$S^*(v_s)=\frac{v_s-\alpha_s}{2-k-\theta}+\tau_0, \qquad \text{if } \frac{2-k-\theta}{1+k-\theta}(\max(\tau_0,\alpha_b)-\tau_0)+\alpha_s\le v_s\le\min(\tau_1,\beta_s) \tag{3.2}$$

$$B^*(v_b)=\frac{v_b-\tau_0}{1+k-\theta}+\tau_0, \qquad \text{if } \max(\tau_0,\alpha_b)\le v_b\le\frac{1+k-\theta}{2-k-\theta}(\min(\tau_1,\beta_s)-\alpha_s)+\tau_0 \tag{3.3}$$

$$B^*(v_b)=\frac{\beta_s-\alpha_s}{2-k-\theta}+\tau_0, \qquad \text{if } \frac{1+k-\theta}{2-k-\theta}(\min(\tau_1,\beta_s)-\alpha_s)+\tau_0<v_b\le\beta_b \tag{3.4}$$

where $\tau_0=\left[(1+k-\theta)\alpha_s+(1-k-\theta)\beta_b\right]/(2-2\theta)$ and $\tau_1=\tau_0+(\beta_b-\alpha_s)/(2-2\theta)$ (see Stein and Parco, 2001 for proof). In the special case for F~uniform[0,100] and G~uniform[0,200] with k=½, equations 3.1 through 3.4 reduce to:

$$S^*(v_s) = \frac{2v_s}{3-2\theta} + \frac{50(1-2\theta)}{1-\theta} \qquad \text{if } 0 \le v_s \le 100 \tag{3.5}$$

$$B^*(v_b) = \frac{2}{3-2\theta} v_b + \frac{50(1-2\theta)^2}{(3-2\theta)(1-\theta)} \quad \text{if } \frac{50(1-2\theta)}{1-\theta} \le v_b \le 100 + \frac{50(1-2\theta)}{1-\theta} \tag{3.6}$$

$$B^*(v_b) = \frac{200}{3-2\theta} + \frac{50(1-2\theta)}{1-\theta} \qquad \text{if } 100 + \frac{50(1-2\theta)}{1-\theta} < v_b \le 200 \tag{3.7}$$

Thus, when $\theta = 0$ (Baseline or "No Bonus" condition) then:

$$S^*(v_s) = \frac{2}{3} v_s + \frac{50}{3} \qquad \text{if } 0 \le v_s \le 100 \tag{3.8}$$

$$B^*(v_b) = v_b \qquad \text{if } 0 \le v_b \le 50 \tag{3.9}$$

$$B^*(v_b) = \frac{2}{3} v_b + \frac{50}{3} \qquad \text{if } 50 \le v_b \le 150 \tag{3.10}$$

$$B^*(v_b) = \frac{350}{3} \qquad \text{if } 150 \le v_b \le 200 \tag{3.11}$$

If instead $\theta = ¼$ (Partial Bonus condition) then:

$$S^*(v_s) = \frac{4}{5} v_s + \frac{100}{3} \qquad \text{if } 0 \le v_s \le 100 \tag{3.12}$$

$$B^*(v_b) = v_b \qquad \text{if } 0 \le v_b \le \frac{100}{3} \tag{3.13}$$

$$B^*(v_b) = \frac{4}{5} v_b + \frac{20}{3} \qquad \text{if } \frac{100}{3} \le v_b \le \frac{400}{3} \tag{3.14}$$

$$B^*(v_b) = \frac{340}{3} \qquad \text{if } \frac{400}{3} < v_b \le 200 \tag{3.15}$$

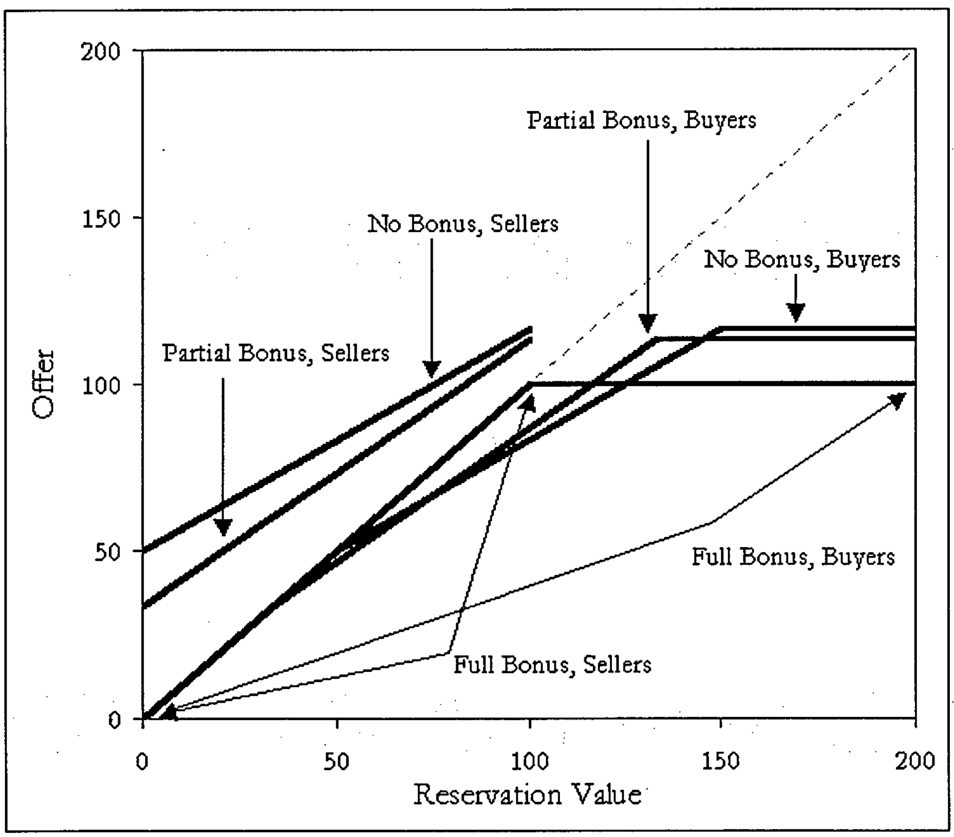
Finally, if $\theta = ½$ (Full Bonus condition), then the LES becomes:

$$S^*(v_s) = v_s \qquad \forall v_s \tag{3.16}$$

$$B^*(v_b) = v_b \qquad \forall v_b \tag{3.17}$$

Figure 3-1 illustrates the equilibrium solutions for the No Bonus (Baseline), Partial Bonus, and Full Bonus experiments with F~uniform[0,100], G~uniform[0,200] and k=½.

FIGURE 3-1. Linear Equilibria for the Bonus Conditions



C. METHOD

<u>(1) Subjects</u>. One-hundred sixty undergraduate and graduate students from the University of Arizona participated in eight experimental sessions, each group consisting of

twenty subjects (see Table 3-1). The subjects were recruited through class announcements and advertisements in the university paper, which promised a $5.00 show-up fee and further payment contingent upon performance. Prior to each session, all subjects were given the opportunity to leave the experiment (without penalty) after receiving their show-up fee.

TABLE 3-1. Bonus Mechanism Experimental Design

Treatment	n^*	Parameter values	Bonus
No Bonus (Baseline)	2 groups	F~[0,100], G~[0,200], k=0.5	0
Partial Bonus	2 groups	F~[0,100], G~[0,200], k=0.5	$(b - s) / 4$
Full Bonus	2 groups	F~[0,100], G~[0,200], k=0.5	$(b - s) / 2$
Reframed Full Bonus	2 groups	F~[0,100], G~[0,200], k=0.5	$(b - s) / 2$

*20 subjects per group and 50 trials per subject across treatments

However, all the subjects elected to remain and participate with compensation contingent on performance. Verbal communication with one another was strictly prohibited. All communication between subjects occurred via networked computers. All subjects were guaranteed anonymity. Each session lasted approximately 60 minutes. Payments varied considerably across subjects ranging from $7.19 to $28.15. The mean earnings for the buyers were $22.84 and the mean earnings for the sellers were $16.10.

(2) Procedure. The same procedure was used for all conditions reported in this study. The eight experimental sessions were conducted in the Economics Science Laboratory and the Enterprise Room at the University of Arizona. Prior to each session, participants drew a card from a stack numbered from 1 to 20 to determine their seat assignment in the laboratory. Subjects 1 through 10 assumed the role of "buyers" and the remaining ten subjects assumed the role of "sellers." Once seated, subjects proceeded to

read the instructions (see Appendices B-E) at their own pace. When every subject completed reading the instructions, the experiment supervisor entertained a brief question and answer period to ensure everyone understood the game design and the payoff function.

Each subject participated in fifty trials of a single stage bargaining game. A between-subjects randomized design was used to prevent reputation effects by randomly pairing buyers and sellers for each trial. All the buyers sat on one side of the laboratory and all the sellers on the other to prevent any transfer of private information between buyers and sellers. Additionally, the twenty computer terminals were well separated from one another preventing communication between the subjects. The subjects were explicitly instructed that their bargaining partners were randomly varied from trial to trial. All fifty rounds were structured in exactly the same way. At the beginning of each round, players privately received a reservation value randomly drawn with equal probability from their respective distributions. To facilitate comparison between the groups and experiments, each buyer was assigned the same fifty randomly chosen reservation values, each in a different random order. The same procedure was used for the sellers. Bargaining continued with buyer (seller) being prompted to state her offer to buy (offer to sell) for the trial. The computer required each subject to confirm his response and warned him if his offer could result in a loss (i.e., if $b>v_b$ or $s<v_s$). Prior to making an offer, all subjects could review previous offers and outcomes by calling up a separate screen. After all twenty subjects responded, the central computer determined for each pair separately whether a deal was struck, and calculated the payoff for each. Subjects were then informed of their decision, their co-bargainer's decision and the gain for the trial. With the exception of the Full Bonus and Reframed Full Bonus conditions, if a deal was reached, players were also informed of the trade price.

D. RESULTS

This section is organized as follows. First, comparisons between the conditions are made to identify any differences in behavior with varying levels of the bonus. Second, individual results are shown for each condition, separately for buyers and sellers. Third, results are aggregated across player types and a typology of strategies is proposed. Finally, theoretical simulated results are compared to the observed data to identify the extent of the bonus on the efficiency of the mechanism.

The interactive nature of the bargaining task dictates that a player's decisions reflect not only his behavior, but also the behavior of all other players with which he interacts. With twenty subjects per group in the reported experiments, each player interacts with every other player of the opposite type five times. Because of the non-independence of decisions, the unit of analysis is not the individual trader, but rather the group of interrelated traders. Furthermore, although previous studies of similar bargaining tasks relied on subject earnings as the primary indicator of individual performance (RS, 1989; RF, 1995; RDS, 1998; DSR, 1998; SDR, 2001), incorporation of the bonus component into the payoff function makes between-condition analysis difficult to interpret. Because the focus of this study is on efficiency, both the number of deals achieved as well as earnings will be considered in assessing performance on the individual, group, and condition level. Using parametric tests on the untransformed data is questionable due to an outlier in the Partial Bonus condition with one of the sellers achieving only eight deals through exceedingly aggressive behavior. This aggressive seller induced a violation of homoskedasticity (σ^2=48.537) in both the deals and earning data. Nevertheless, the outlier was retained, given no evidence existed of erroneous play. Therefore, variance in the Partial Bonus condition differs drastically from

the Full Bonus (σ^2=14.06) and Reframed Bonus (σ^2=17.96) conditions. To facilitate aggregate analysis, a Wilcoxon Rank Sum Test for two independent samples was used to compare the number of deals made for each of the two groups within condition for significant differences. No significant differences were found within condition between the groups[22] using nonparametric tests.[23]

<u>(1) Between Treatment Comparisons</u>. A Kruskal-Wallis test[24] for the four independent condition samples identified a significant between-condition difference (H=502.90, p<0.00001). Comparison of the single-stage, non-bonus data from RDS (1998) to the No Bonus condition yielded no significant differences using both parametric[25] and non-parametric techniques (Wilcoxon z=1.718, p<0.094). Similarly, there was no significant difference between the No Bonus and Partial Bonus conditions (z=0.431, p<0.668) or between the Partial Bonus and the Full Bonus condition (z=1.270, p<0.104). However, the Full Bonus differed significantly from both the No Bonus (z=2.132, p<0.037) condition as well as the Reframed Bonus (z=4.411, p<0.001) conditions. Parametric tests of the comparisons using the Student t-test also yielded consistent results with the nonparametric tests reported here.

<u>(2) Individual data.</u>

<u>(a) Partial Bonus, Buyers.</u> The individual plots for the buyers of the Partial Bonus condition in Figure 3-2a are similar to those of the No Bonus buyers (Figure 2-2a), but with

[22] No Bonus condition (z=0.703, p<0.486); Partial Bonus condition (z=0.257, p<0.799); Full Bonus condition (z=0.284, p<0.778); Reframed Full Bonus condition (z=1.380, p<0.176).
[23] Despite noncompliance with the heteroskedasticity assumption, a two-tailed Student-t test still revealed no significant differences within-condition at α <0.05 for all four conditions.
[24] Compared to a parametric one-way ANOVA yielding and F=16.929 with p<0.0001
[25] For comparison purposes only.

notably more variation both within[26] and between[27] subjects. Like the No Bonus buyers, many of the Partial Bonus buyers bid more aggressively than predicted by the LES, specifically Subjects 4, 5, 10, 14, 19 and 20. Note that the piece-wise function represents the Bayesian-Nash equilibrium for the Partial Bonus condition. The Partial Bonus LES, identified by equations (3.12) through (3.16), lies between the No Bonus and Full Bonus LES solutions with a slope of $^4/_5$. A notable difference between the No Bonus and Partial Bonus buyers is the tendency to shave. This tendency seems to be attenuated for subjects with a propensity to truthfully reveal value. Subjects 6, 7, and 12 all closely follow a truth-telling strategy with negligible shaving. The remaining buyers predominantly follow strategies that approximate the would-be equilibrium path of this condition. Also similar to the No Bonus buyers, three of the Partial Bonus subjects made offers where $b > v_b$, namely Subjects 3, 9, and 16. Subject 3 continued to occasionally submit $b > v_b$ offers through Trial 16 where he received his first negative payoff. Subject 9 had a very small differential with $b > v_b$ bids and never found herself in the domain of losses. Consequently, she continued to make such offers[28] through Trial 47. Subject 16 submitted two $b > v_b$ offers. On Trial 6, Subject 16 bid $b = B(35) = 80$. Because his co-bargainer asked $s = 143$, no deal was achieved. The last instance occurred on Trial 12 with $b = B(35) = 80$ resulting in a negative payoff. Clearly, in all of these cases $b > v_b$, although usually occurring in earlier trials, appears to be deliberate. However, in all cases, such behavior ceases with the realization of a negative outcome.

---

[26] Standard deviation of bids in the No Bonus condition (35.61) increased dramatically in the Partial Bonus condition (42.68).

[27] Significantly different at $p = 0.028$ between conditions.

[28] Trial 47 had the largest differential with $b = 99$ and $v_b = 92$. Profit from the trade was 90 francs.

FIGURE 3-2a. Partial Bonus, Buyers

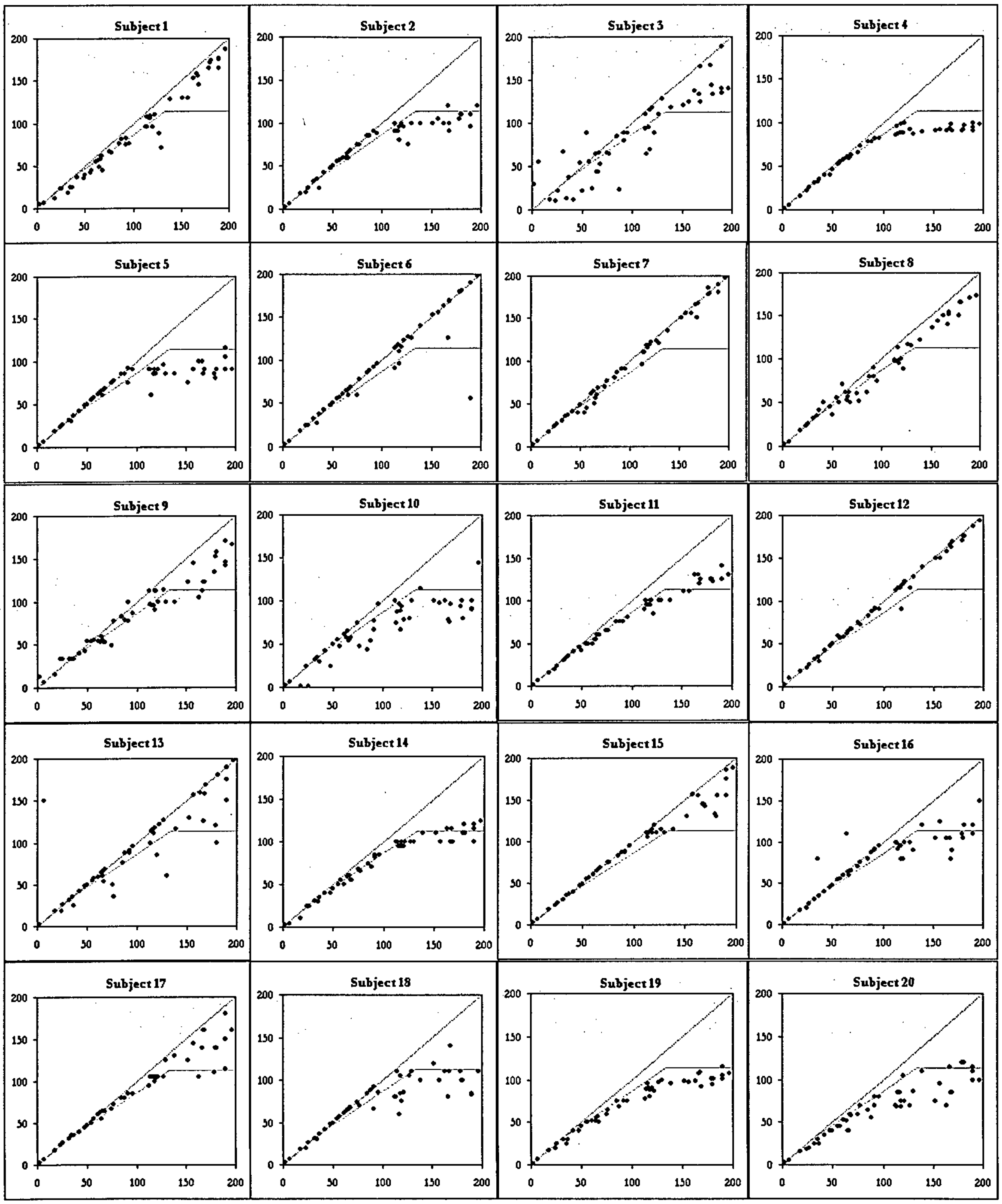
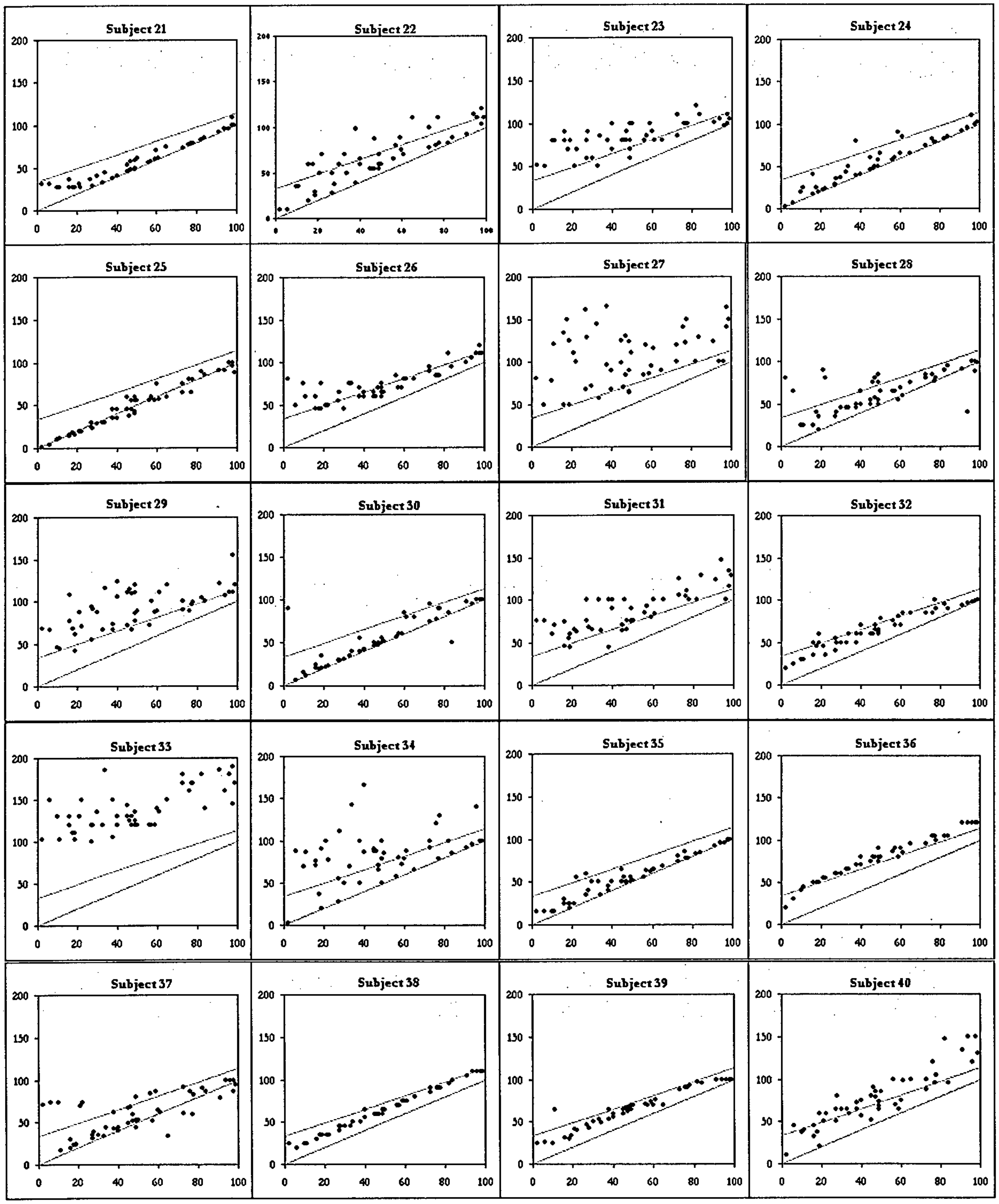


FIGURE 3-2b. Partial Bonus, Sellers



<u>(b) Partial Bonus, Sellers.</u> Figure 3-2b illustrates the decision of the sellers for the Partial Bonus condition. The variation of asks between the No Bonus and Partial Bonus conditions is not significant, however, some subjects, namely, 21, 24 25, 30, and 33 gravitate toward truth-telling strategies, with some shaving evident in all cases. On the other hand, Subjects 23, 27, 29, 31, 33, 34, and 40 "stand their ground" and resist the aggressive bidding of the buyers in the face of information disparity. The case of the outlier for Subject 28 where $s < v_s$ appears to be an error as it occurred on Trial 1 resulting in a loss, not again repeated. Similarly, for Subject 30, as the $s < v_s$ ask occurred on Trial 2. However, Subject 37 submitted $s < v_s$ asks through Trial 49, occasionally incurring small negative losses throughout, while usually realizing a profit.

<u>(c) Full Bonus, Buyers.</u> In the Full Bonus condition, the LES dictates that both players truthfully reveal their respective valuations as their independent offers. However, for sake of comparison, the No Bonus LES line remains on the individual plots. Figure 3-3a identifies the individual decisions of the buyers in the Full Bonus condition. It is somewhat misleading to identify truth-telling as a unique linear Bayesian-Nash equilibrium in the face of information asymmetry.[29] Although sellers have a dominant strategy to make truthful offers for all v_s, truthful bidding holds for the buyer only up to β_s, the upper limit of F. When $v_b \geq 100$, buyers could theoretically bid any amount up to β_b, the upper limit of G, and still achieve ex post efficiency. In the current design, buyers bidding truthfully above 100 would only improve the sellers earnings unilaterally. Thus, caution must be taken when interpreting results for buyers in the Full Bonus and Reframed Bonus conditions for $v_b > 100$.

[29] Although truth-telling is a strongly dominant strategy for sellers, it is only <u>weakly</u> dominant for buyers given their information-advantage.

FIGURE 3-3a. Full Bonus, Buyers

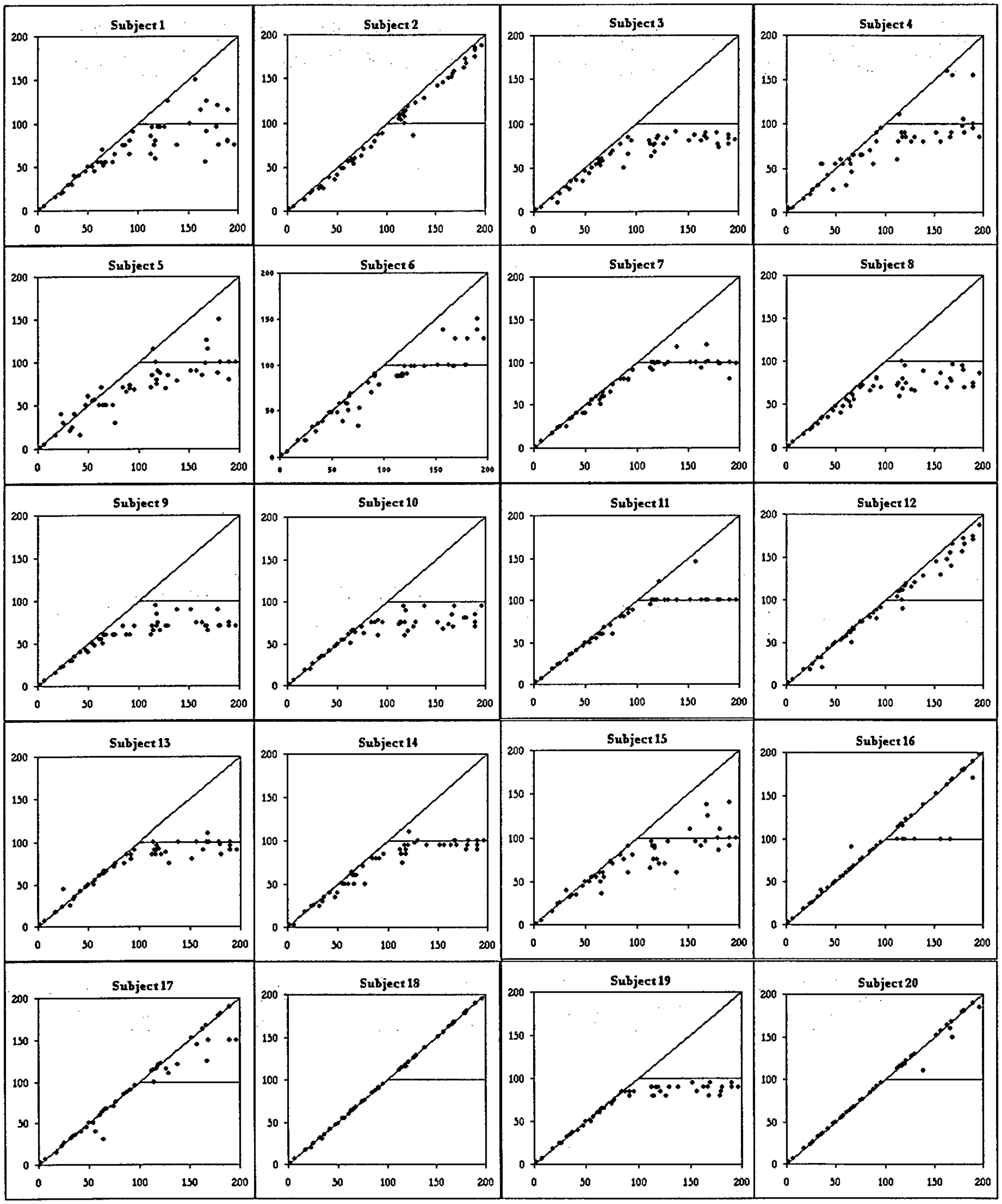
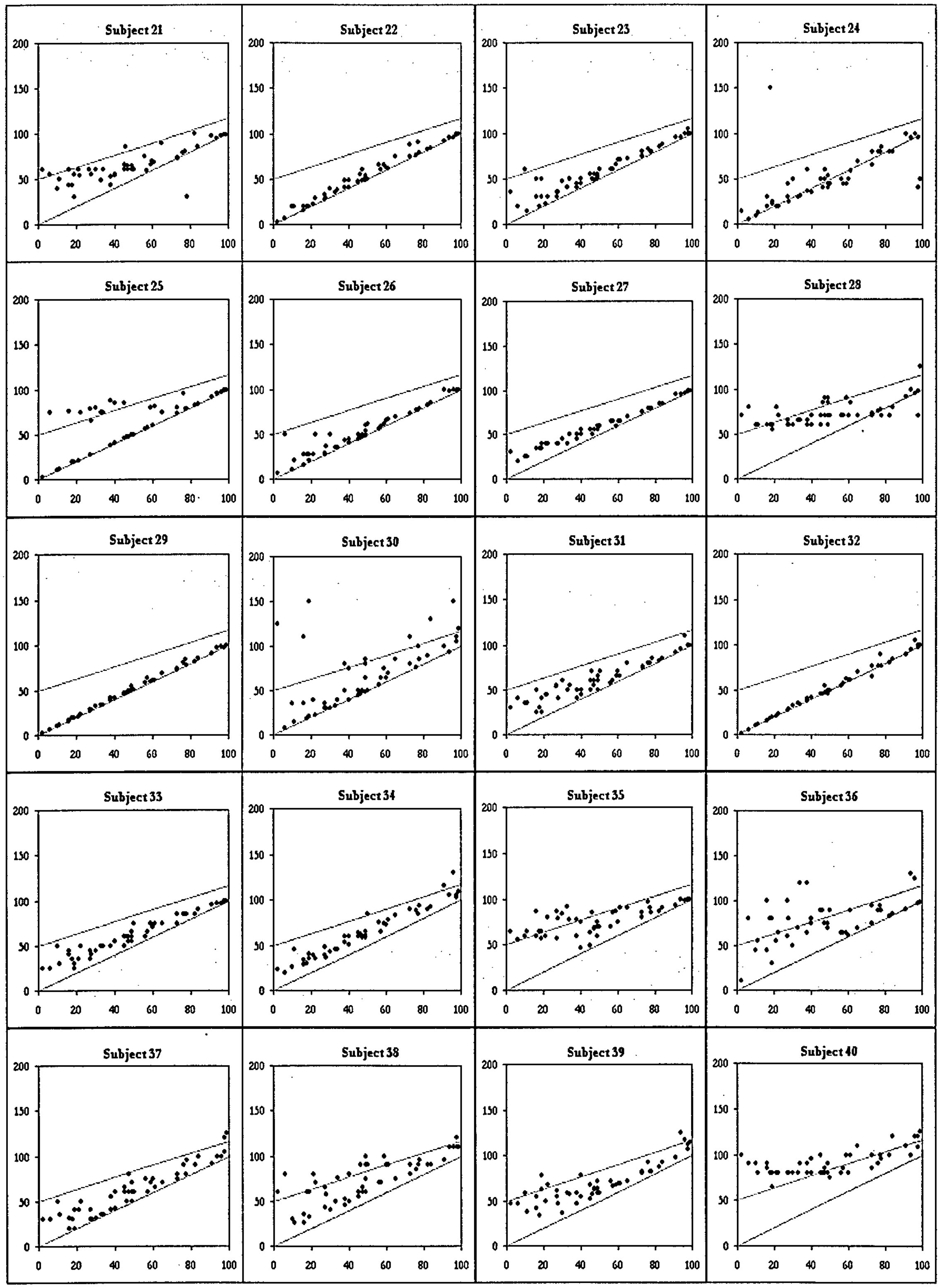


FIGURE 3-3b. Full Bonus, Sellers



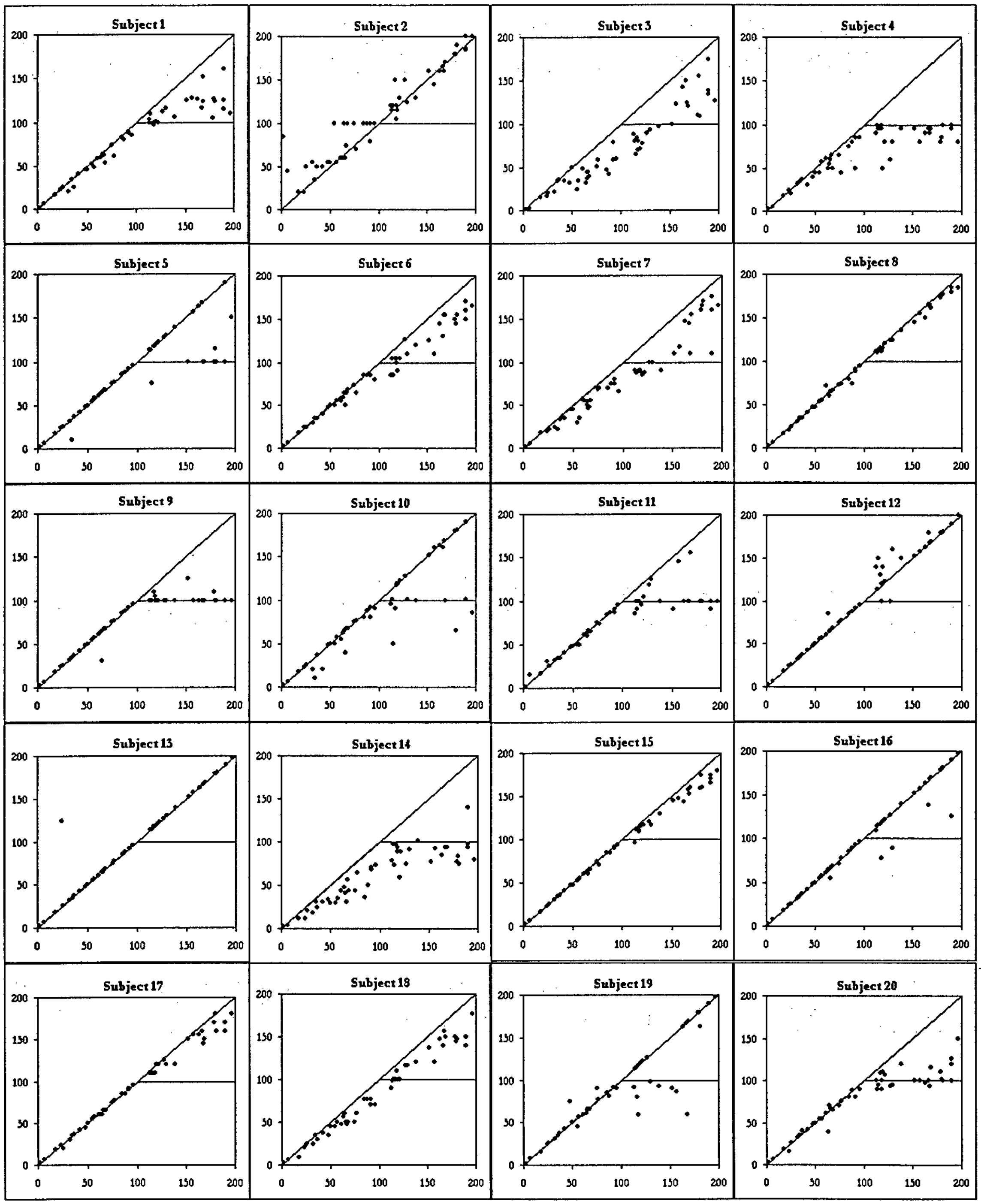
Subjects 2, 7, 11, 12, 13, and 16-20 closely approximate a truthful strategy for $0<v_b<100$. Within this subgroup of truth-tellers, only Subjects 2, 12, 16, 18, and 20 continued to bid relatively truthfully for $v_b>100$. The vertical line through the center of each graph represents the extension of the Full Bonus LES to $b=B(v_b\geq 100)=100$. In addition to $b=v_b$, any bid at or above $b\geq 100$ for $v_b>100$ is a weakly dominant strategy. Consistent with such a strategy, Subjects 11, 13, and 19 deliberately suppressed the sellers' earnings by shaving their offers considerably for higher values of v_b. Finally, as noted earlier, one of the potential problems in implementing the full bonus is the emergence of the collusion equilibrium. However, in this condition, in only a few cases did $b>v_b$ (Subjects 1, 4, 5, 13, and 15). Inspection of the raw data confirms that these bids were most likely attributable to errors and learning as similar to behavior exhibited in the No Bonus and Partial Bonus conditions. There appears to be no evidence of collusive behavior with the sellers in the Partial Bonus condition.

(d) Full Bonus, Sellers. Although the No Bonus LES is not applicable to the sellers in the Full Bonus condition, it remains on the individual plots as in the case of the buyers for comparative purposes (see Figure 3-3b). Similar to the buyers, plots of the sellers' behavior provide no evidence for attempts at collusion. In the few cases where $s<v_s$, these offers appeared to be the results of an error (Subject 21) or trial-and-error behavior (Subjects 24 and 28) which ceased immediately upon realizing a negative outcome. Subjects 22, 24, 26, 29, and 32 all followed a truth-telling strategy. Subject 25 also converged to truthful revelation after the first 20 trials. Subjects 28, 30, 35, 36, 38, and 40 deviated from a truth-telling strategy to their detriment behaving much too aggressively. The remaining subjects shaved their asks consistent with seller behavior observed in the No Bonus and Partial Bonus conditions.

(e) Reframed Full Bonus, Buyers. Theoretically, results from the Reframed Bonus condition should not differ from results of the Full Bonus condition. Nevertheless, the variation between the Full and Reframed Full Bonus conditions for the buyers was significant at p=0.013. Similarly to the interpretation of results for the buyers of the Full Bonus condition, the bids of interest lie in the range $50 < v_b < 100$. Figure 3-4a shows the individual decisions of the buyers in the Reframed Bonus condition. Subjects 2 and 12 differ from all other buyers in either Full or Reframed Bonus conditions in that each made an attempt at collusion. Unlike the supposition of BK of bidding at β_b (the upper limit of G), there is stronger evidence with data from Subject 2 to bid at β_s (the upper limit of F) when endowed with an information advantage. Only twice did Subject 2 bid 200, and both times for high values of v_b. She bid 100 eight times when $b > v_b$. In total, Subject 2 made 31 out of 50 bids where $b > v_b$.[30] Subject 12 also made an attempt at collusion bidding $b > v_b$ ten times. The first occurrence of $b > v_b$ was for a $v_b < 100$ and resulted in a loss. Subject 12 continued to make nine more $b > v_b$ offers, but for $v_b > 100$ and all resulted in gains. After four additional $b > v_b$ bids, no further indication of collusive behavior emerged. The outlier evident in Subject 13 is clearly an error as he bid $b = v_b$ for all trials except Trial 4. On Trial 4, Subject 13 bid $b = B(124) = 24$, which is presumably a typo. The other three $b > v_b$ bids made by Subject 8 and Subject 19 appear to be deliberate decisions "testing the water" with none resulting in negative outcomes. Similar to the Full Bonus condition, six subjects (Subjects 1, 3, 4, 7, 10, 14, and 18) bid strategically to their detriment. However, the remaining subjects showed

[30] Subject 2 bid $b > v_b$ twice during Trials 1-10 but bid $b > v_b$ consistently during Trials 40-50. Twenty-eight of the 32 $b > v_b$ offers yielded non-negative outcomes. The negative outcomes ranged from −2 to −47 with the largest losses incurred at very low values of v_b.

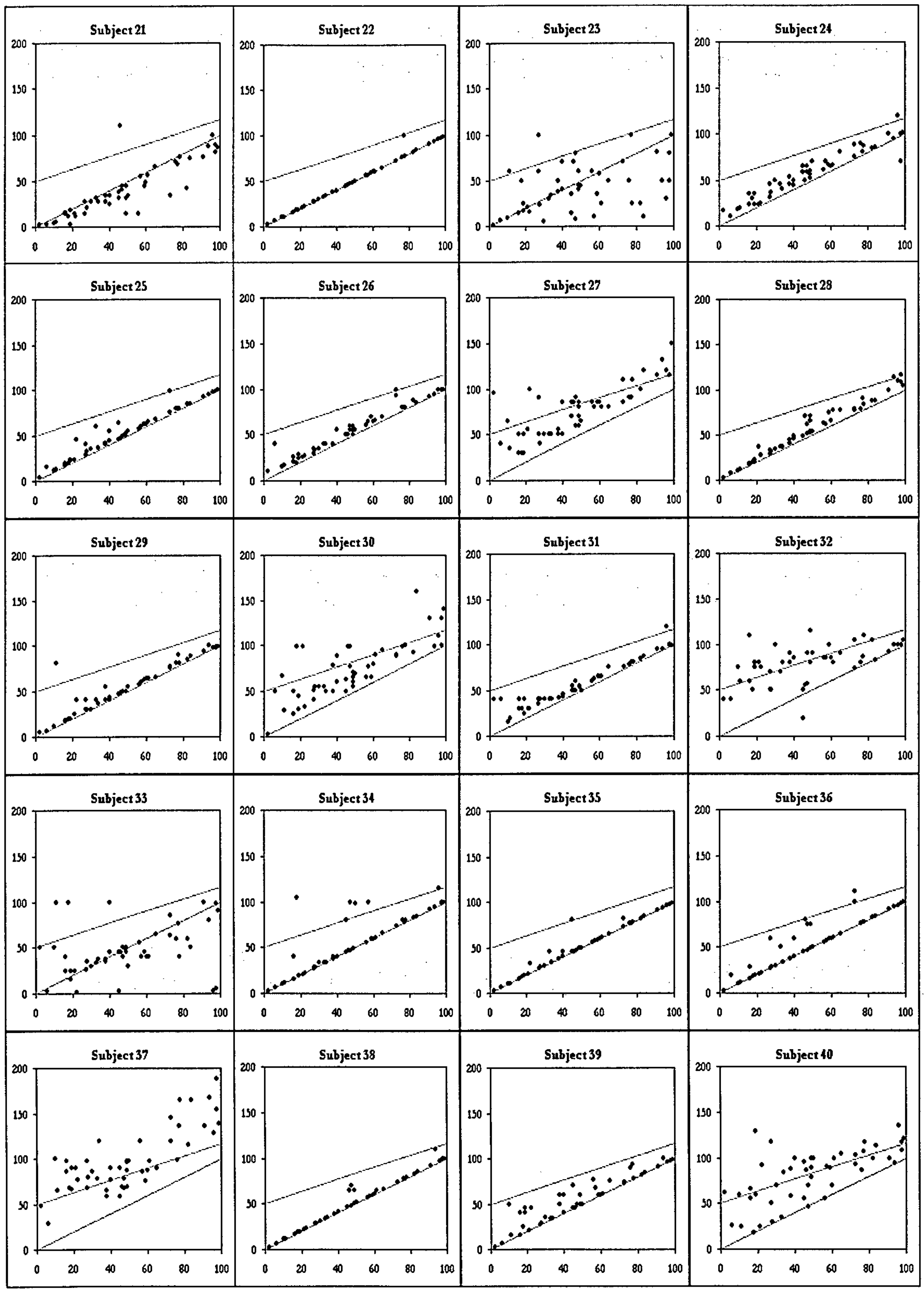
FIGURE 3-4a. Reframed Full Bonus, Buyers



more consistency with a truth-telling strategy, particularly on later trials. Subjects 9, 11, and 20 bid $b=v_b$ for $v_b<100$, and shaved all $b\geq100$ unilaterally suppressing seller earnings just as did three subjects in the Full Bonus condition. The primary difference between the Full and Reframed Bonus conditions with respect to the buyers was in the degree of shaving offers for high values of v_b. The amount of shaving decreased significantly with the revised payoff function of the Reframed Bonus condition.

(f) Reframed Full Bonus, Sellers. The variation of the sellers' offers in the Reframed Bonus condition (Figure 3-4b) are significantly different from the sellers' offers in the Full Bonus condition at $p=0.004$. The difference is manifested in a larger standard deviation of offers in the Reframed Full Bonus condition (30.98) compared to that of the Full Bonus condition standard deviation (25.87). This difference is due mainly to unsuccessful efforts by several of the sellers to engage in collusive behavior. In the Full Bonus condition, none of the twenty subjects showed any indication of collusive behavior, however, in the Reframed Bonus condition, Subjects 21, 23, and 33 submitted a considerable number of offers where $s<v_s$. Subject 21 was the most consistent but least aggressive seller in attempting to collude. Only during the first two trials of play did $s>v_s$ for Subject 21. During Trials 3-45, Subject 21 offered $s<v_s$ with an average deviation between s and v_s of 10.8. In the remaining five trials, Subject 21 offered $s=v_s$. Not once did Subject 21 make the minimum offer of $s=1$. Even with $v_s=2$, Subject 21 offered $s=S(2)=2$. Subject 23 made fewer collusive offers of $s<v_s$, but had nearly twice as large of a deviation (s-v_s=21) for $s<v_s$ offers. Nevertheless, Subject 23 made most (33 out of 50) offers of $s<v_s$. Like Subject 21, Subject 23 never made the minimum offer of $s=1$. Making 56% $s<v_s$ offers with an

FIGURE 3-4b. Reframed Full Bonus, Sellers



average deviation on these offers of 18.4, Subject 33's behavior was very similar to that of Subject 23. Unlike Subjects 21 and 23, Subject 33 did make a minimum offer of $s=1$, but only once and early in play during Trial 4. Only two other points occurred with $s<v_s$, once each with Subject 24 and 32. Subject 24 made a single $s<v_s$ offer on Trial 33 which resulted in a negative outcome. Subject 32 also made a single $s<v_s$ offer on Trial 49, which resulted in a gain. Neither of the decisions appears to be erroneous. Most of the remaining sellers shaved only occasionally and usually in earlier trials in varying and limited degrees. Six of the sellers pursued predominantly truthfully revealing strategies. Also similar to the Full Bonus condition, five subjects, Subjects 27, 30, 32, 37, and 40 acted far too aggressively to their detriment. The preponderance of the decisions from nine sellers fell between the truth-telling and LES functions. Even when explicitly informed that individual offers would have no effect on earnings, given that a deal was made, Subjects 30, 32, 37, and 40 made a considerable number of strategic offers and consequently forfeited a substantial amount of earnings. As with the Full Bonus Sellers, the No Bonus LES remains on the plots for the Reframed Full Bonus Sellers for comparison purposes only but has no relevance otherwise.

(3) Typology of Decisions. Table 3-2 reports a categorization of offers for buyers and sellers in the bonus conditions. Truthful offers are defined as $b=B(v_b)=v_b$ for the buyer and $s=S(v_s)=v_s$ for the seller. Any $b>v_b$ or $s<v_s$ is defined as a collusive offer. Strategic offers are technically defined as any offer, which is characterized by shaving ($b<v_b$ or $s>v_s$), however, for purposes of comparison, offers that are strategic in nature, but within five units of the reservation value are characterized as "negligible shaving." The results indicate that the propensity to bid strategically decreased monotonically for both buyers and sellers across the four conditions. Although observed behavior did not change significantly between the

Partial and Full Bonus conditions, the degree of shaving decreased slightly causing an increase in the 'negligible shaving' category from 20.3% to 23.9%. Surprisingly, the number of truthful offers by the buyers decreased slightly between the Partial and Full Bonus conditions as the bonus increased. Comparing the Full to the Reframed Bonus condition for the buyers truthful offers increased dramatically from 17% to 31%. Collusive bidding by the buyers, although increasing in the Reframed Bonus condition still accounted for only 5% of the bids.

With regard to the sellers, implementation of the bonus in increasing levels induced a decrease in strategic offers, an increase in truthful offers, and relatively no change in collusive offers comparing the Partial Bonus to the Full Bonus condition. Strategic offers declined further for the sellers in the Reframed condition while truthful offers nearly doubled moving from 11% to 22%. Similarly to the buyers, collusive offers increased dramatically between the Full and Reframed Bonus conditions accounting for over 10% of the asking offers by the sellers.

TABLE 3-2. Percentage of Offer Types by Condition

	Buyers				Sellers			
	No Bonus	Partial	Full	Reframed	No Bonus	Partial	Full	Reframed
Strategic offers	67.9%	57.9%	57.3%	44.9%	81.2%	75.1%	60.5%	40.5%
Negligible shaving	19.5%	20.3%	23.9%	19.0%	14.6%	17.7%	24.8%	26.6%
Truthful offer	9.7%	19.7%	17.0%	30.9%	2.5%	3.0%	10.6%	22.2%
Collusive offer	2.9%	2.1%	1.8%	5.2%	1.7%	4.2%	4.1%	10.7%

Because negligible shaving approximates a truth-telling strategy, both truthful offers and negligible shaving are graphed as "honest" offers. Figure 3-5 illustrates a comparison between the four conditions categorizing strategic, honest, and collusive offers for buyers and sellers separately. For both buyers and sellers, strategic offers dominate honest offers in

the Partial Bonus and Reframed Bonus conditions. Only when the payoff function is simplified in the Reframed Bonus condition does the frequency of honest offers exceed the frequency of strategic offers for both players. Although movement in the direction of truthful revelation is evident in the Reframed Bonus condition, nearly half of the offers continued to be characterized by strategic bidding with a considerable amount of shaving.

FIGURE 3-5. Categorization of Offer Types

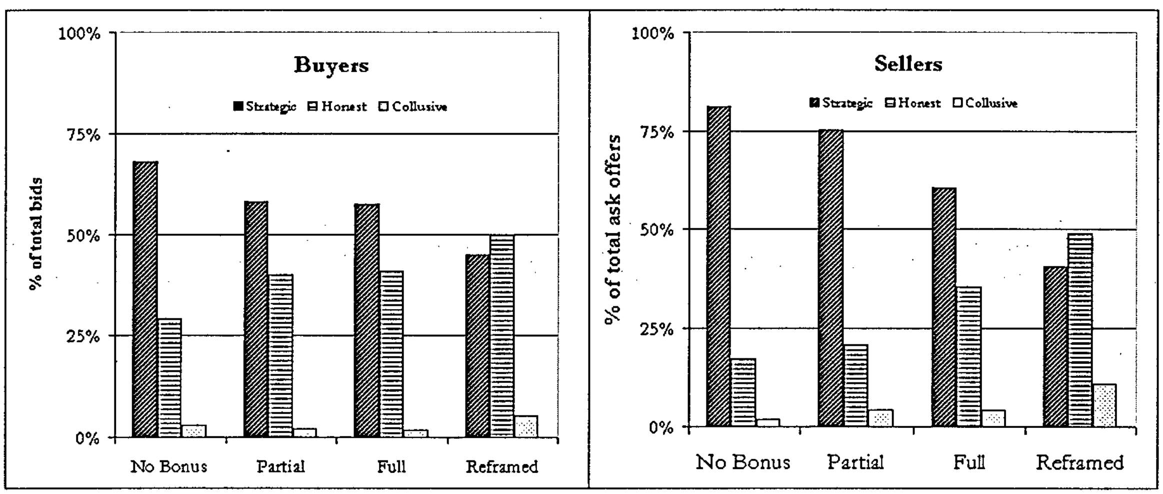


Figure 3-6 identifies the running average[31] mean squared deviation (MSD) between reservation values and offers for both player types. The graphs illustrate that the buyers generally demonstrated a stronger propensity to shave than the sellers in all conditions except the Partial Bonus condition. Because several of the sellers in the Partial Bonus condition 'stood their ground,' the buyers in this condition were less able to use their information advantage. This attribute is manifested in a population dynamic where the seller

[31] In steps of 10.

and buyers alike learned to shave in best response to their co-bargainer population. Some evidence exists to support population dynamics by comparing the plots of the MSD in the No Bonus condition in later trials. As sellers learned to increase shaving resulting in a positive slope, the buyers shave less yielding a negative slope. Looking beyond the Partial Bonus condition, the results from the remaining three conditions illustrate a propensity to bid more truthfully not only with the implementation of the unique full bonus, but also when the full bonus is reframed. Furthermore, in both the Full and Reframed Full Bonus conditions, learning is evident for both buyers and sellers as the MSD decreases over time.

FIGURE 3-6. Mean Squared Deviation Running Average (step 10) Between Offer and Reservation Value

(4) Regression Analysis. Because the LES and truthful revelation functions are linear in all conditions for the sellers,[32] a simple linear regression model is sufficient for estimating slope and intercept coefficients. In the No Bonus condition, the equilibrium (represented by

[32] Given F and G

the LES function) dictates an intercept of 50 and a slope of $^2/_3$. All of the coefficients reported in Table 3-3 are significant at $p<0.001$. The slope coefficients for the Partial and Full Bonus conditions both increased by 0.07 between the first block (Trials 1-25) and last block (Trials 26-50) while the respective intercepts decreased. The Reframed Bonus condition yielded intercepts decreasing from 28.5 to 17.8 and a slope increasing from 0.72 to 0.85. However, neither coefficient came close to the truthful predictions of a 1.0 slope and 0 intercept in either the Full or Reframed Bonus conditions. In all of the conditions, the amount of variance explained by the regression model, denoted by R^2, increased between the first and last blocks. However, because of the diversity of individual strategies of the sellers within each condition, the aggregate R^2 results are not that impressive.

TABLE 3-3. Regression Results, Sellers

	Block1: Trials 1-25			Block 2: Trials 26-50			Trials 1-50		
	Slope	Intercept	R^2	Slope	Intercept	R^2	Slope	Intercept	R^2
Predicted									
$\theta=0$ (No Bonus)	0.67	50.0		0.67	50.0		0.67	50.0	
$\theta=0.25$ (Partial)	0.80	33.3		0.80	33.3		0.80	33.3	
$\theta=0.50$ (Full)	1.0	0		1.0	0		1.0	0	
Observed									
No Bonus	0.74	32.6	0.60	0.70	38.0	0.20	0.72	35.2	0.32
Partial	0.72	39.7	0.38	0.79	33.2	0.40	0.75	36.5	0.39
Full	0.69	32.7	0.51	0.76	23.9	0.64	0.72	28.5	0.56
Reframed	0.88	17.2	0.53	0.81	18.6	0.56	0.85	17.8	0.54

Note: All reported statistics are significantly different than zero at $p<0.001$, $\alpha=0.05$

Due to the theoretical piece-wise nature of the equilibrium for buyers in the No Bonus condition, spline regression was used to isolate slopes and conjoining pivot points at $v_b=50$ and $v_b=150$. Similarly for buyers in the Partial Bonus condition, spline regression was

fit at conjoining pivot points at v_b=50 and v_b=150 to facilitate direct comparison. The spline model is merely an extension of the single linear regression model and any non-significant changes in slope can be interpreted as the dummy variable accounting for negligible variance.

Table 3-4a shows the results of the spline model for Block 1 and Table 3-4b for Block 2. Table 3-4c shows results across all trials. In the three conditions of the bonus implementation, the slope coefficient for $v_b<50$ approaches 1.0 as predicted by both the LES and truth-telling equilibrium. All intercept coefficients for $v_b<50$ are insignificant at $p<0.05$ for both blocks. The slope coefficient for the Partial Bonus condition in the range $50 \leq v_b \leq 150$ is exceedingly close to the LES prediction during Block 1 and increases to 0.75 during Block 2 as expected. The Full Bonus condition yielded quite unexpected results. Although the expected slope coefficient is 1.0, the observed coefficients of 0.60 and 0.65 are not only considerably more aggressive than the dominant strategy, but also more aggressive than the dominated LES. The slope coefficient for the Full Bonus condition in the upper-range of v_b decreased from 0.40 in the first block to zero in the second block. Note that Block 2 observed coefficients of the Full Bonus condition are nearly identical to the (irrelevant) No Bonus LES. The Reframed Bonus results are a drastic improvement over the Full Bonus condition with insignificant slope and intercept coefficients in Block 1 for the mid- and upper-ranges of v_b reducing the spline model to a simple linear regression model. However, in Block 2, the buyers became more aggressive yielding a slope coefficient of 0.34, which is significant at the $p<0.001$ level. This evidence demonstrates that although the subjects move in the direction of the dominant truthful revelation equilibrium, they do not reach it.

TABLE 3-4a. Spline Regression Results, Buyers, Block 1: Trials 1-25

	$v_b < 50$		$50 \leq v_b \leq 150$		$150 < v_b$		
	Slope	Intercept	Slope	Intercept	Slope	Intercept	Adj. R^2
LES	1.00	0.0	0.67	50.0	0.00	116.7	
No Bonus	0.90***	2.7	0.57***	47.9	0.25**	104.6	0.75
Partial	0.88***	4.8	0.68*	48.6	0.35**	116.3	0.77
Full	1.03***	-2.3	0.60***	49.3	0.40*	109.7	0.75
Reframed	0.87***	4.0	##		##		0.81
Truth-telling	1.00	0.0	1.00	50.0	1.00	150.0	

TABLE 3-4b. Spline Regression Results, Buyers, Block 2: Trials 26-50

	$v_b < 50$		$50 \leq v_b \leq 150$		$150 < v_b$		
	Slope	*Intercept*	*Slope*	*Intercept*	*Slope*	*Intercept*	*Adj. R^2*
LES	1.00	0.0	0.67	50.0	0.00	116.7	
No Bonus	1.01***	-1.2	0.57***	47.9	0.25***	104.6	0.77
Partial	1.01***	-1.7	0.75*	48.5	0.46**	123.9	0.83
Full	1.03***	-1.4	0.65**	50.2	-0.01***	115.0	0.67
Reframed	0.99***	-0.6	##		0.34***	147.9	0.81
Truth-telling	1.00	0.0	1.00	50.0	1.00	150.0	

TABLE 3-4c. Spline Regression Results, Buyers, Trials 1-50

	$v_b < 50$		$50 \leq v_b \leq 150$		$150 < v_b$		
	Slope	*Intercept*	*Slope*	*Intercept*	*Slope*	*Intercept*	*Adj. R^2*
LES	1.00	0.0	0.67	50.0	0.00	116.7	
No Bonus	0.96***	1.0	0.58***	48.8	0.169***	106.6	0.76
Partial	0.94***	2.0	0.71**	48.8	0.43***	119.5	0.80
Full	1.04***	-2.0	0.62***	49.9	0.19***	112.3	0.71
Reframed	0.93***	1.9	##		0.51***	139.8	0.81
Truth-telling	1.00	0.0	1.00	50.0	1.00	150.0	

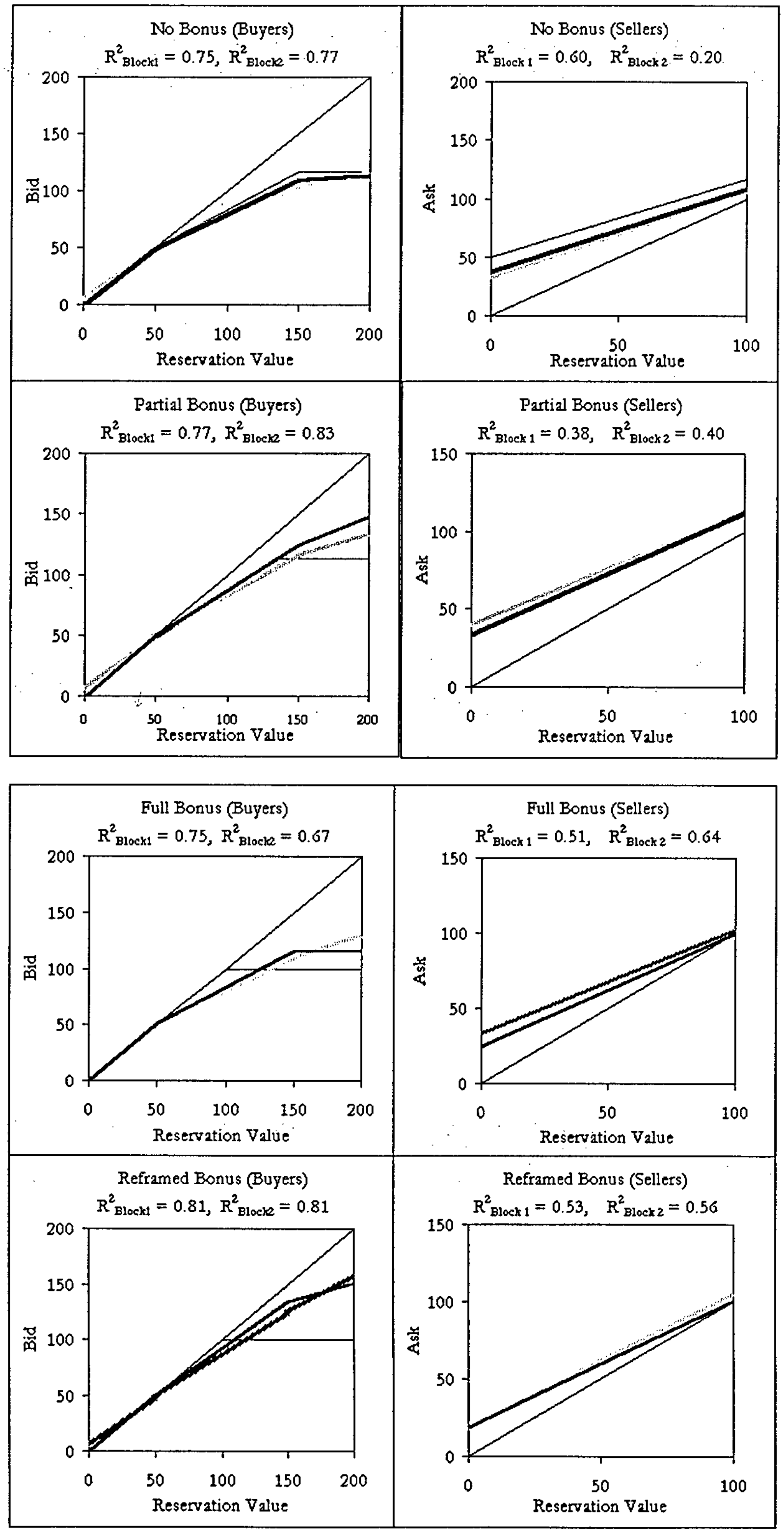
Note 1: *p<0.1, **p<0.01, ***p<0.001 testing whether the coefficient is significantly different than zero
Note 2: # # insufficient data to estimate a different spline function slope coefficient in the particular range

The R^2 scores for the buyer spline model are much improved over the seller model accounting for 70-80% of the variance across conditions.

Figure 3-7 shows the aggregate plots across all trials for each condition with the light-gray line representing Block 1 offers and the dark line indicating Block 2. Results from the No Bonus condition show strong support for the LES in the case of the buyers with consistent shaving for v_b>50. Likewise, the sellers were effectively 'pushed down' as predicted by the information disparity hypothesis (RDS, 1998). With the exception of the buyer graph of the Partial Bonus condition, block 2 offers from the other bonus implemented conditions all move in the direction of truthful revelation in comparison to aggregate block 1 offers for buyers and sellers alike. The buyer graphs are inconsistent when comparing the Partial Bonus condition with the Full Bonus condition for reasons noted earlier in the analysis of Figure 3-6. The sellers' graphs on the other hand are much more predictable showing an incomplete, but consistent trend toward the truth-telling equilibrium from the No Bonus LES. For the sellers, there is a small, yet identifiable move in the direction toward truthful revelation with improved model fit (increasing R^2) in each bonus implemented condition.

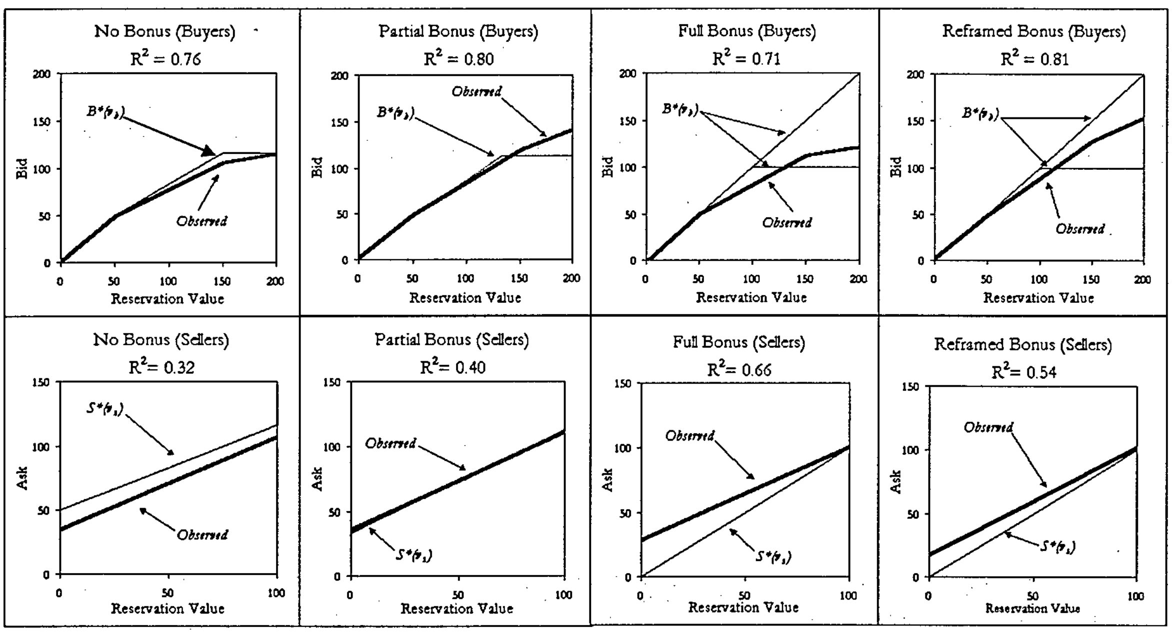
(5) Aggregate Results. Figure 3-8 combines blocks 1 and 2 of Figure 3-7 into a single function identifying the aggregate plots across all trials for each condition. Overall, for the buyers, there is an identifiable move toward truth-telling comparing the No Bonus condition with the Reframed Bonus condition. The aggressiveness of buyers in the Full Bonus condition is apparent in their conformity to the No Bonus LES. Only the sellers in the Partial Bonus condition demonstrated support for equilibrium play. The buyers in the Full

FIGURE 3-7. Regression plots by Block



Bonus condition were the most aggressive and quite effective in inducing a shift in the aggregate behavior of the sellers. The aggressiveness of the buyers in the Full Bonus condition not only resulted in drastically reduced realized individual earnings from lost deals, but effectively 'forced' the sellers toward the truthful-telling equilibrium. The results for buyers are ambiguous in the range of information disparity. The sellers' graphs on the other hand are much more predictable, revealing an incomplete, but consistent convergence toward the truthful revelation equilibrium with increasing levels of the bonus.

FIGURE 3-8. Regression Plots by Player Type



<u>(6) Efficiency Analysis</u>. Table 3-5 reports the bonus costs and efficiency by condition. Although aggregate earnings were monotonically higher with increasing levels of bonus implementation, efficiency levels decreased given the simultaneous surplus-increasing effect of incorporating the bonus into the payoff function. Efficiency actually *decreased* with a

partial bonus and *further decreased* with the full bonus due to players continuing to bid strategically despite its dominated characteristics foregoing not only the gains from trade, but also an equal amount of bonus earnings for each missed deal. Although efficiency in the Reframed Full Bonus condition improved dramatically, it still was 20% less than the LES predicted outcome. Considering only the gains from trade, the actual size of the surplus was constant across conditions. Ignoring the bonus payoffs, efficiency in achieving gains from trade fell slightly from 86% to 85% with the implementation of the partial bonus but increased to 90% and 94.4% in the Full and Reframed Full Bonus conditions, respectively. The costs incurred for these improvements were quite large ranging from 13,190 francs in the Partial Bonus condition to 38,723 francs in the Reframed Full Bonus condition. These bonuses comprised 20-41% of the total earnings across the bonus conditions. Observed percentage of agreements increased monotonically from 71.5% in the No Bonus condition to 89.0% in the Reframed Bonus condition, well below LES predictions for the samples of reservation values drawn during the experiment.

TABLE 3-5. Efficiency Results by Condition

	No Bonus	*Partial Bonus*	*Full Bonus*	*Reframed Bonus*
Observed deals	71.5%	73.6%	79.4%	89.0%
Predicted deals	65.4%	83.0%	100.0%	100.0%
Observed Efficiency with bonus	86.2%	71.9%	66.9%	80.1%
Observed Efficiency without bonus	86.2%	85.4%	90.0%	94.4%
Predicted Efficiency	92.7%	96.5%	100.0 %	100.0 %
Cost of Bonus implementation	0	13190	25757	38723
Percentage of overall earnings	0	20.8%	32.7%	41.1%

Table 3-6 reports the number of observed deals by subject for all conditions separately as well as the simulated number of deals that would have been realized if either party had played a truthful or collusive strategy. Let A-A (actual-actual)[33] denote the observed results of both players; T-T (truth-truth) denote a game with each player playing $b=v_b$ or $s=v_s$; and, C-C (collude-collude) denote the game where $b=200$ and $s=1$.[34] Due to the heteroskedastic nature of the observed variance, medians are reported in lieu of means. The median number of deals for the buyers increased monotonically from 26.5 in the No Bonus condition to 31.0 in the Full Bonus condition. The Reframed Full Bonus condition induced an increase to 34.0. Likewise for the sellers, median number of deals achieved increased monotonically from 27.5 in the No Bonus condition to 30.0 in the Full Bonus condition. The Reframed Full Bonus condition further induced an increase to 34.0.

<u>(7) Theoretical Simulation Analysis</u>. Although mutual truthful revelation is not a dominant strategy in the No Bonus and Partial Bonus condition, it is the Pareto efficient outcome given the assumption of interim individual rationality. In the Full and Reframed Full Bonus conditions, mutual truth-telling becomes the Bayesian-Nash (albeit Pareto deficient) equilibrium. With the unique full bonus implemented to theoretically induce truthful revelation, the collusion equilibrium achieves Pareto efficiency. In the absence of collusive action, the T-T strategy should achieve ex post efficiency by maximizing the number of nonnegative deals dominating both the A-T and T-A strategies. However, because of collusive offers[35] ($b>v_b$ or $s<v_s$), some players achieved a greater number of deals

[33] The player's decision is listed on the left of the hyphen and the co-bargainer's decision is listed on the right.
[34] The choice to set $v_s=1$ instead of $v_s=0$ was deliberate as sellers were not allowed to ask less than 1 in the experiment.
[35] Inclusive of errors.

than they otherwise would have, given that their co-bargainer bid truthfully. Thus, T-T is occasionally dominated by A-T in the simulation. Buyer 13 in the Partial Bonus condition would have achieved fewer deals under a T-T strategy due to a realized deal from a single outlying bid. In the Reframed Full Bonus condition, Buyers 2 and 12 as well as Sellers 21 and 23 also would have made fewer deals had they bid truthfully due to their strong propensities to submit collusive offers. It should be noted that merely achieving efficiency is not an accurate indicator of performance if interim individual rationality is violated, which is the case with collusive offers. Because the T-T equilibrium is the Bayesian-Nash in the Full and Reframed Full Bonus conditions, unilateral deviation from the truth-telling strategy, even in the direction of the Pareto-efficient collusion equilibrium, will necessarily reduce earnings while the number of deals will increase beyond ex post efficiency. Because every simulation combination with one party bidding collusively will yield 100% realized deals, they have been excluded from Table 3-6. Similarly to the A-T simulation, the T-A simulation plays truthful offers against a player's co-bargainer's actual decisions, which should yield fewer deals than the T-T equilibrium. The exceptions occurred in the Reframed Bonus condition where Buyers 1, 4, and 10 made a greater number of deals than predicted due to losing propositions made by Sellers 21 and 23 in their collusion attempts.

Comparing the A-A observed data to a simulation where the co-bargainers bid honestly against play (A-T), only Seller 25 in the Partial Bonus condition would have made fewer deals in A-A than he would have in A-T. Inspection of the data reveals that Seller 25 made several $s < v_s$ deals that he should not have made while foregoing other deals through

TABLE 3-6. Deal simulation

		No Bonus				Partial Bonus				Full Bonus				Reframed Bonus			
Sub		*A-A*	*T-T*	*A-T*	*T-A*	*A-A*	*T-T*	*A-T*	*T-A*	*A-A*	*T-T*	*A-T*	*T-A*	*A-A*	*T-T*	*A-T*	*T-A*
1	Buyer	26	36	33	29	27	36	33	29	31	36	32	34	33	36	33	37
2	Buyer	29	36	34	32	26	36	34	32	31	36	36	35	37	36	39	34
3	Buyer	27	38	34	32	31	38	34	32	26	38	32	33	33	38	36	36
4	Buyer	25	37	35	32	30	37	35	32	33	37	36	37	33	37	32	38
5	Buyer	31	37	34	31	22	37	34	31	34	37	35	36	36	37	37	37
6	Buyer	26	40	39	34	33	40	39	34	29	40	37	33	38	40	37	38
7	Buyer	36	42	41	35	33	42	41	35	32	42	37	38	34	42	36	38
8	Buyer	30	38	34	34	27	38	34	34	29	38	30	37	34	38	38	36
9	Buyer	25	41	39	32	29	41	39	32	31	41	34	38	36	41	40	36
10	Buyer	25	36	33	32	25	36	33	32	26	36	32	32	35	36	36	37
11	Buyer	29	36	32	30	26	36	32	30	26	36	36	29	26	36	35	29
12	Buyer	25	36	35	31	30	36	35	31	28	36	35	31	33	36	37	34
13	Buyer	27	38	39	32	31	38	39	32	27	38	35	31	38	38	38	37
14	Buyer	29	37	35	31	24	37	35	31	30	37	34	34	26	37	29	35
15	Buyer	26	37	37	37	36	37	37	37	31	37	36	35	33	37	37	34
16	Buyer	26	40	39	29	29	40	39	29	32	40	40	33	35	40	39	35
17	Buyer	22	42	41	34	31	42	41	34	34	42	41	36	40	42	41	40
18	Buyer	26	38	36	32	25	38	36	32	32	38	38	32	30	38	34	34
19	Buyer	27	41	39	29	22	41	39	29	29	41	39	32	35	41	41	38
20	Buyer	27	36	32	30	23	36	32	30	33	36	36	33	32	36	33	35
21	Seller	25	34	32	32	30	34	32	32	28	34	32	30	37	34	39	32
22	Seller	27	43	38	41	34	43	38	41	38	43	43	38	42	43	43	42
23	Seller	27	36	25	33	20	36	25	33	27	36	32	32	39	36	39	33
24	Seller	27	39	39	37	36	39	39	37	33	39	38	33	34	39	38	36
25	Seller	33	38	37	38	38	38	37	38	33	38	36	38	36	38	38	37
26	Seller	26	36	31	34	26	36	31	34	30	36	33	34	33	36	33	36
27	Seller	31	35	22	33	15	35	22	33	30	35	33	32	29	35	31	34
28	Seller	34	40	37	37	31	40	37	37	25	40	33	36	35	40	38	39
29	Seller	20	38	23	34	17	38	23	34	33	38	38	34	32	38	36	35
30	Seller	30	42	39	37	36	42	39	37	25	42	35	34	32	42	32	40
31	Seller	32	34	22	31	18	34	22	31	30	34	31	33	29	34	32	31
32	Seller	33	43	39	42	36	43	39	42	42	43	43	40	30	43	34	40
33	Seller	28	36	16	36	8	36	16	36	28	36	29	34	35	36	36	35
34	Seller	23	39	31	37	24	39	31	37	33	39	34	39	37	39	38	38
35	Seller	29	38	38	37	37	38	38	37	30	38	34	37	35	38	38	35
36	Seller	19	36	30	33	28	36	30	33	26	36	27	35	34	36	36	35
37	Seller	19	35	35	33	34	35	35	33	31	35	32	35	25	35	26	35
38	Seller	29	40	38	39	35	40	38	39	29	40	32	39	38	40	40	40
39	Seller	22	38	33	38	29	38	33	38	28	38	33	37	35	38	37	35
40	Seller	30	42	33	39	28	42	33	39	25	42	31	41	30	42	34	40
Total Deals		522	762	680	680	560	762	680	680	604	762	695	695	677	762	723	723
Median (B)		26.5	37.5	35.0	32.0	28.0	37.5	35.0	32.0	31.0	37.5	36.0	33.5	34.0	37.5	37.0	36.0
Median (S)		27.5	38.0	33.0	37.0	29.5	38.0	33.0	37.0	30.0	38.0	33.0	35.0	34.5	38.0	36.5	35.5
Median		27.0	38.0	35.0	33.0	29.0	38.0	35.0	33.0	30.0	38.0	34.5	34.0	34.0	38.0	37.0	36.0
Deals Made		54.4%	76.2%	68.0%	68.0%	56.0%	76.2%	68.0%	68.0%	60.4%	76.2%	69.5%	69.5%	67.7%	76.2%	72.3%	72.3%

TABLE 3-7a. Earnings Simulation, No Bonus and Partial Bonus Conditions

		No Bonus					Partial Bonus				
Sub		*A-A*	*T-T*	*T-A*	*C-T*	*C-A*	*A-A*	*T-T*	*T-A*	*C-T*	*C-A*
1	Buyer	1803	1439	1168	(1228)	(1602)	1654	2158	1594	636	(218)
2	Buyer	1578	1390	1073	(1295)	(1699)	1746	2085	1661	536	(16)
3	Buyer	1395	1417	1096	(1287)	(1630)	1722	2126	1609	547	(218)
4	Buyer	1628	1458	1145	(1216)	(1632)	2079	2186	1829	654	96
5	Buyer	1552	1424	1127	(1219)	(1635)	1418	2135	1589	650	(199)
6	Buyer	1638	1517	1125	(1062)	(1615)	1664	2275	1720	885	61
7	Buyer	1400	1481	1125	(1164)	(1618)	1671	2222	1641	732	(37)
8	Buyer	1452	1570	1231	(1098)	(1596)	1796	2354	1736	831	2
9	Buyer	1647	1533	1194	(1068)	(1512)	1881	2299	1758	876	(36)
10	Buyer	1743	1495	1207	(1156)	(1568)	1773	2242	1697	744	(103)
11	Buyer	1474	1439	944	(1228)	(1780)	1636	2158	1451	636	(371)
12	Buyer	1444	1390	1038	(1295)	(1857)	1314	2085	1298	536	(587)
13	Buyer	1105	1417	890	(1287)	(1998)	1430	2126	1442	547	(406)
14	Buyer	1195	1458	1123	(1216)	(1721)	1688	2186	1562	654	(368)
15	Buyer	1521	1424	1068	(1219)	(1714)	1616	2135	1529	650	(243)
16	Buyer	1388	1517	1046	(1062)	(1724)	1658	2275	1484	885	(479)
17	Buyer	1227	1481	967	(1164)	(1827)	1726	2222	1582	732	(251)
18	Buyer	1470	1570	1024	(1098)	(1797)	1745	2354	1691	831	(213)
19	Buyer	1669	1533	1108	(1068)	(1685)	1651	2299	1520	876	(208)
20	Buyer	1738	1495	1132	(1156)	(1762)	1665	2242	1587	744	(376)
21	Seller	960	1259	745	(202)	(772)	1384	1889	1330	897	280
22	Seller	1139	1727	825	413	(535)	1770	2591	1736	1818	957
23	Seller	930	1365	753	(26)	(720)	1387	2047	1364	1161	419
24	Seller	1014	1540	798	196	(609)	1712	2310	1665	1492	818
25	Seller	1039	1600	895	245	(492)	1675	2399	1692	1566	828
26	Seller	919	1490	780	85	(660)	1734	2235	1630	1326	690
27	Seller	991	1537	859	136	(564)	1295	2305	1610	1403	667
28	Seller	906	1249	741	(147)	(652)	1133	1873	1186	979	284
29	Seller	1041	1366	809	25	(591)	1213	2049	1377	1236	526
30	Seller	1089	1580	929	262	(456)	1807	2369	1832	1591	1006
31	Seller	838	1259	823	(202)	(701)	1342	1889	1358	897	309
32	Seller	1117	1727	952	413	(366)	1709	2591	1643	1818	850
33	Seller	978	1365	825	(26)	(595)	802	2047	1463	1161	516
34	Seller	1207	1540	923	196	(457)	1324	2310	1538	1492	685
35	Seller	1237	1600	926	245	(458)	1797	2399	1739	1566	883
36	Seller	1083	1490	901	85	(531)	1625	2235	1493	1326	545
37	Seller	913	1537	746	136	(706)	1539	2305	1463	1403	518
38	Seller	997	1249	787	(147)	(655)	1539	1873	1425	979	567
39	Seller	1080	1366	778	25	(590)	1386	2049	1373	1236	527
40	Seller	1197	1580	878	262	(471)	1739	2369	1656	1591	838
Total	Francs	50734	58862	38493	(21610)	(45544)	63444	88293	62549	41115	8539
Mean Buyer		1503	1472	1091	(1179)	(1698)	1677	2208	1599	709	(208)
Mean Seller		1034	1471	833	99	(579)	1496	2207	1529	1347	635
Overall Mean		1268	1472	962	(540)	(1139)	1586	2207	1564	1028	213

TABLE 3-7b. Earnings Simulation, Full and Reframed Bonus Conditions

		Full Bonus					Reframed Bonus				
Sub		*A-A*	*T-T*	*T-A*	*C-T*	*C-A*	*A-A*	*T-T*	*T-A*	*C-T*	*C-A*
1	Buyer	2495	2877	2582	2500	2099	2457	2877	2485	2500	1965
2	Buyer	2413	2780	2427	2366	1866	2363	2780	2442	2366	1884
3	Buyer	2140	2834	2540	2381	1929	2472	2834	2545	2381	1926
4	Buyer	2292	2915	2528	2524	2062	2554	2915	2829	2524	2378
5	Buyer	2383	2847	2501	2518	2087	2768	2847	2827	2518	2442
6	Buyer	2490	3033	2605	2832	2247	2786	3033	2786	2832	2518
7	Buyer	2232	2962	2521	2627	2102	2544	2962	2577	2627	2120
8	Buyer	2560	3139	2802	2759	2156	2828	3139	2834	2759	2407
9	Buyer	2300	3065	2663	2819	2302	2680	3065	2680	2819	2344
10	Buyer	2170	2989	2462	2644	2014	2822	2989	2936	2644	2499
11	Buyer	1962	2877	1991	2500	1378	2299	2877	2343	2500	1620
12	Buyer	2121	2780	2136	2366	1443	2169	2780	2206	2366	1567
13	Buyer	1709	2834	1989	2381	1255	2382	2834	2406	2381	1869
14	Buyer	2173	2915	2332	2524	1773	2140	2915	2467	2524	1854
15	Buyer	2029	2847	2178	2518	1740	2610	2847	2621	2518	1914
16	Buyer	2194	3033	2204	2832	1747	2691	3033	2691	2832	2256
17	Buyer	2077	2962	2106	2627	1603	2439	2962	2439	2627	2027
18	Buyer	2319	3139	2319	2759	1629	2527	3139	2589	2759	2058
19	Buyer	2281	3065	2468	2819	1854	2246	3065	2387	2819	1892
20	Buyer	2425	2989	2425	2644	1799	2450	2989	2517	2644	1975
21	Seller	1390	2518	1413	1995	757	1846	2518	1910	1995	1309
22	Seller	1646	3454	1646	3223	1328	2277	3454	2277	3223	2041
23	Seller	1340	2729	1355	2347	874	1818	2729	2052	2347	1553
24	Seller	1433	3080	1559	2789	1104	2219	3080	2262	2789	1871
25	Seller	1503	3199	1641	2887	1281	2189	3199	2201	2887	1825
26	Seller	1615	2980	1657	2567	1171	2384	2980	2388	2567	1931
27	Seller	1459	3073	1468	2670	961	2320	3073	2370	2670	1919
28	Seller	898	2497	1300	2104	836	1756	2497	1776	2104	1423
29	Seller	1280	2732	1284	2447	891	2137	2732	2198	2447	1890
30	Seller	1320	3159	1483	2921	1142	2207	3159	2391	2921	2127
31	Seller	2072	2518	2083	1995	1504	2059	2518	2065	1995	1472
32	Seller	2222	3454	2226	3223	1982	2414	3454	2651	3223	2371
33	Seller	1746	2729	1772	2347	1355	2079	2729	2219	2347	1761
34	Seller	2048	3080	2113	2789	1802	2242	3080	2251	2789	1933
35	Seller	2051	3199	2199	2887	1868	2579	3199	2579	2887	2159
36	Seller	2213	2980	2385	2567	1938	2533	2980	2545	2567	2116
37	Seller	2260	3073	2289	2670	1841	2387	3073	2657	2670	2241
38	Seller	1437	2497	1680	2104	1279	2020	2497	2039	2104	1638
39	Seller	2081	2732	2208	2447	1881	2251	2732	2251	2447	1918
40	Seller	1931	3159	2390	2921	2116	2359	3159	2530	2921	2216
Total	Francs	78710	117724	83930	103840	64996	94303	117724	97219	103840	79229
Mean Buyer		2238	2943	2389	2596	1854	2511	2943	2580	2596	2076
Mean Seller		1697	2943	1808	2596	1396	2204	2943	2281	2596	1886
Overall Mean		1968	2943	2098	2596	1625	2358	2943	2430	2596	1981

strategic play that he should have. The net result was a decrease in one deal lost in an A-T simulation. Nevertheless, unilateral deviation by playing A-A is dominated by A-T in all cases. Theory would also predict that number of deals would increase when comparing A-A to T-A. Except in the cases of collusive offers,[36] the Bayesian-Nash property of T-T is substantiated.

Tables 3-7a and 3-7b report the earnings of the subjects in each bonus condition as well as simulated earnings[37] in a format similar to that reported in Table 3-6. Observed behavior (A-A) and mutual truth-telling (T-T) are reported. Additionally, a collusive strategy pitted against both a truth-telling strategy (C-T) and actual behavior (C-A) is computed for all conditions. For purposes of demonstrating the Pareto and Nash properties of the T-T equilibrium, the truthful revelation against co-bargainer behavior (T-A) is also reported.

Table 3-7a shows results from a simulation of earnings for the No Bonus and Partial Bonus condition. In both of these conditions, the T-T pair is Pareto-efficient but not Nash stable. However, consistent with findings of RDS (1998) and SDR (2001), the buyers uniformly extract a disproportionately larger share of the gains from trade at the expense of the seller. In the No Bonus condition, over half of the buyers outperformed the T-T equilibrium. Because there is no incentive to deviate at all from the LES, no player can improve his position by playing a collusive strategy as evidenced by the very small and otherwise negative earnings of the simulation. With the introduction of the Partial Bonus, some incentive exists not only to move toward truthful revelation, but also toward collusion,

[36] Seller 23 (Full Bonus), Buyers 2 & 13 and Sellers 21& 23 (Reframed Bonus)

[37] The "simulation" referred to for both the deals-made and earnings results are computed by pitting hypothetical offers against one another for the actual reservation values of each pairing to ascertain "what would have been."

as evidenced by the general increases in payoffs in C-T and C-A when compared to the No Bonus condition. In the Partial Bonus condition, all players could have improved with mutual deviation to the T-T equilibrium but do not due to the instability of the equilibrium since T-A strictly dominates T-T. In three instances (Buyers 5, 6 and 13), buyers would have improved their earnings had they employed a truthful strategy over the strategy that they played. Likewise, eight sellers (Sellers 25, 27-31, 33, and 34) could have also improved by playing honestly. In many of these cases, considerable earnings were foregone in one or two missed deals that overshadowed any additional earnings gained from overly strategic play.

Table 3-7b reports results from the simulation from the Full Bonus and Reframed Full Bonus conditions where the Pareto-efficient strategy was C-C and the Bayesian-Nash strategy was T-T. T-T strictly dominates all strategies except for C-C. Additionally, T-A strictly dominates all A-A strategies demonstrating the unilateral deviation away from truth-telling was detrimental to the deviating player. Playing a collusion strategy against actual opponent play would have reduced earnings of all players with the exception of Buyer 9 in the Full Bonus condition. Because Buyer 9 engaged in such aggressive strategic behavior, the losses due to missed deals and consequently missed bonuses were greater than any losses incurred by bidding 200 each trial.

(8) Bonus Discussion. Implementation of the bonus has a significant impact on behavior in a two-person bargaining game of incomplete information, but not nearly to the extent predicted. The Partial Bonus had no significant impact on behavior. Surprisingly, sellers showed an increase in strategic behavior compared to the No Bonus condition. Replication of DSR Experiment 1 via the No Bonus condition demonstrated support for the information disparity hypothesis: the information advantaged player bid more aggressively

than predicted by the LES extracting a greater proportion of the surplus at the expense of the information disadvantaged player who bid less aggressively. Only when the bonus was increased to the unique amount to induce truth-telling as a weakly dominant strategy did behavior differ significantly from the No Bonus or Partial Bonus conditions. The primary difference in the Partial Bonus condition was observed in sellers demonstrating lower aggregate levels of strategic behavior while buyers persisted at No Bonus levels. The percentage of agreements improved, but not to the extent predicted. Efficiency levels would have increased if bonus payments were excluded but not significantly more than what would be expected if players followed the LES. Scarce attempts at collusive bidding yielded deals not predicted by theory while many deals continued at impasse due to persistent strategic bidding with a net increase in deals made. Players making collusive offers failed to transmit useful information to co-bargainers by making offers at the obvious focal points of collusion (buyers bidding b=200 or b=100; sellers asking s=1). Instead, players inversely shaved offers to increase the probability of consummating a deal to extract the bonus at potentially small losses.

Implementation of the Full Bonus failed to achieve the predicted efficiency. Although truthful-revelation was the weakly dominant strategy, the majority of players, both buyers and sellers, continued to engage in strategic behavior to their individual detriment. One possible explanation is that most people are entrenched in the concept of strategic play and have a difficult time recognizing that truthful revelation can be an optimal strategy. A second possible explanation is that the players simply did not understand the payoff functions and falsely believed that their individual offers had an effect on their respective outcomes. Yet, even in the Reframed Full Bonus condition where subjects were explicitly

and repeatedly informed that "*individual offers [had] no effect of one's earnings and only determined whether or not a deal was made*" the propensity to shave continued to persist for many of the subjects. Thus, even when players knew that their offer could not affect their earnings, they continued to resist truthful revelation.

Another interesting finding in the Full and Reframed Bonus data is the effect of the information asymmetry. Several buyers in each condition conformed to the truthful revelation equilibrium up to the upper limit of the seller's reservation value distribution, β_s=100, but unilaterally suppressed seller's earnings for any reservation value above v_b=100. These *stingy* buyers, although conforming to the truthful equilibrium and achieving optimal efficiency given that sellers play truthfully, behaved strategically ensuring the sellers didn't profit asymmetrically on their information advantage. Because very few sellers ever asked for more than s=100 in the Full Bonus condition, buyers could effectively achieve equity in the profits. However, in the Reframed Full Bonus condition, a considerable number of asks exceeded $s \geq 100$ providing buyers an incentive to bid honestly, even at reservation values above v_b=100. Although such strategic bidding on the part of the sellers was a dominated strategy, taking losses early of forgone deals due to strategic bidding increased overall aggregate earnings for the sellers by pushing the buyers up for higher reservation values. Average seller earnings increased by more than twice that of the buyers between the Full Bonus and Reframed Full Bonus conditions, although the martyred sellers leading the charge to push the buyers up inevitably fared worse.

No evidence developed to support the collusion equilibrium. Even though collusive offers doubled between the Full and Reframed Full Bonus condition, these offers accounted

for less than 10.7% of total offers and had no apparent effects on co-bargainers to move toward collusion. Furthermore, the majority of the offers came from only a few subjects.

The "simplification" or "framing" of the payoff function in the Reframed Full Bonus condition had a significant effect despite the theoretical prediction of no effect. One explanation is that subjects "better understood" the game and therefore recognized the dominant strategy of truthful revelation. However, a competing explanation cannot be dismissed: subjects may have been more confused with the reframing of the payoff function without reference to a trade price. In the face of this potential greater ambiguity, subjects could have elected to bid truthfully using the reservation value as a focal point for offers. The Reframed Full Bonus condition made no mention of trade price and informed subjects that opponents' offers would affect profit if a deal was made. Traditional bargaining institutions, with which most people are familiar, rely on the concept of a trade price. By eliminating this concept, the environment becomes less familiar. Thus, it is possible that reframing the Full Bonus condition introduced greater uncertainty into the game. Caution must be taken before concluding the Reframed Full Bonus condition improved understanding based on average player earnings alone.

CHAPTER IV: TWO-STAGE MECHANISM

A. INTRODUCTION

Although interesting in its own right, theoretical and experimental investigation of the single-stage mechanism is only a first step in furthering our understanding of bargaining institutions under incomplete information. Because many bargaining contexts involve multiple offers, a natural progression in this line of research is to establish whether or not additional stages of bargaining affect the outcome of the game.[38] The single-stage mechanism can be viewed as a model of the final offer following a sequence of offers and counteroffers. This chapter explores general n-stage bargaining model as a sequence of simultaneous offers but curtails the (offer, counteroffer, offer, counteroffer, etc.) process by constraining n=2 and a costless first stage where a binding agreement can be achieved during either stage 1 or stage 2 if $b \geq s$. Ascertaining efficiency improvements of the multi-stage mechanism is of primary importance

B. THEORY

The dilemma faced in a n-stage bargaining game of incomplete information is quite similar to that of the single-stage game. Each player wants to force as favorable of a trade price as possible without foregoing a profitable agreement. However, the multi-stage aspect adds additional complexity by allowing an agreement at any stage i, i=1,2. With costless stages of bargaining, players have no incentive to make serious offers in early stages since future stages occur with certainty.

[38] This is, clearly, the case in most face-to-face negotiations.

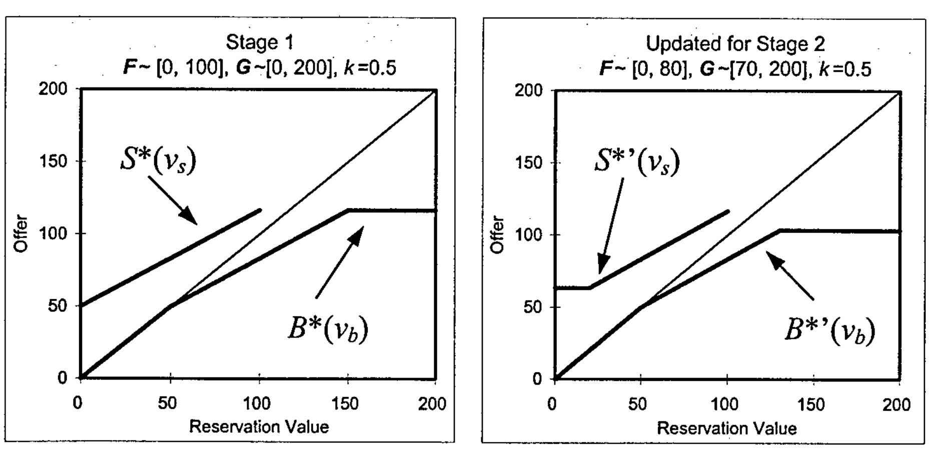
Stein notes that as stages of bargaining become costly or the value of the surplus diminishes, the incentive to reveal diminishes and converges to the single-stage equilibrium (2001). He has developed an *n*-stage bargaining model following from the original LES model. In his model, during each stage players independently and simultaneously make offers until either an agreement or a predefined number of stages is reached. Stein shows that the process of bidding may reveal information about a player's reservation value. This leads to a different game on each successive stage where there may be complete information, one sided-uncertainty, or two-sided uncertainty. He develops an *n*-stage model with a time discounting factor, δ, which can be interpreted as the probability that the game continues to the next stage. He proves that if $\delta = 0$, the unique linear equilibrium is the LES solution under two-sided uncertainty. However, as $\delta \to 1$ when *n*=2, the range in which players make serious offers on earlier stages diminishes providing no benefit for coming to a deal during the first stage.

The two-stage experiment of this chapter closely relates to Stein's model but with $\delta = 1$, which his model does not directly address. Thus, the prediction follows the logic that as $\delta \to 1$, neither player should make serious offers during the first stage. Therefore, the two-stage game relegates to a single-stage game since there exists *no* incentive ($\delta = 1$) to unilaterally reveal any information until the final stage. However, because the possibility of achieving a binding agreement in stage 1 exists, the single-stage LES cannot be assumed to be the outcome optimizing Bayesian-Nash equilibrium of the two-stage game, prima facie. Given that players reveal information during stage 1, stage 2 predictions are not testable since the LES prediction for stage 2 is conditional on equilibrium play in stage 1. The

appropriate solution concept here is the subgame perfect equilibrium, as shown by Stein. Proof of this two-stage, risk-neutral, utility maximizing equilibrium is an area for future theoretical development.

Numerical analysis (simulation) of the LES demonstrates that the single-stage LES cannot be a Bayesian-Nash equilibrium for stage 1 play in a two-stage game with $\delta = 1$. Consider that a buyer makes an offer b=70 during stage 1 and the seller offers s=80. There is no deal since b<s. These offers, however, under Stein's model, would be considered *serious* since each reveals some information about v_b and v_s. The seller could reasonably infer that 70≤v_b≤200 and update the information regarding common knowledge of the buyer's reservation value distribution from G~uniform[0,200] to G'~uniform[70,200]. Likewise, updating the seller distribution would result in F~uniform[0,100] in stage 1 to F ~uniform[0,40] in stage 2. Figure 4-1 graphically depicts the dual shift in the LES from mutually revealing stage 1 offers. In this example, the buyer should not bid more than $B^{*\prime}(v_b)_{max}$=103.33, a 13.33 reduction from the maximum single-stage LES prediction of $B^*(v_b)_{max}$=116.67.

FIGURE 4-1. Information Updating of the Linear Equilibrium Strategies



Similarly, the seller's minimum ask increases from $S^*(v_s)_{min}$=50 to $S^{*'}(v_s)_{min}$=63.33. Because of a mutual deviation toward revealing information in stage 1, both players increase the likelihood of reaching an agreement in stage 2 thereby increasing efficiency of the mechanism. However, the usefulness of the stage 1 offers in updating the LES for each of the players is dependent upon the particular reservation values for the trial and conditional upon players bilaterally revealing information. Both players also run the risk of striking a deal during stage 1 by revealing information when their co-bargainer does not resulting in a less-than-favorable trade price. For this reason, given that stage 2 will occur with certainty, neither player has an incentive to reveal any information in stage 1 and should not make a serious offer during stage 1 as it can only allow a player's co-bargainer to update her stage 2 offer function increasing the likelihood of a more aggressive offer during the second stage of bargaining.

The prediction for this game is that neither player will reveal any information about his reservation value during stage 1 and will play the single-stage LES during stage 2. However, if either player deviates and reveals information about her reservation value and no deal is made during stage 1, then players will update the priors and play the (revised) LES during stage 2.

C. Method

(1) Design Considerations. Paramount to this study was to determine whether or not the addition of a second-stage fundamentally alters results from the single stage game. To make direct comparisons with the previously published studies of an asymmetric

information single-stage game (see Chapter II for a complete exposition), the same pairs of random reservation values and subject matching sequence was implemented to control for unsystematic variance. Using a recurring single-play design with randomized matching, each player was randomly matched with a co-bargainer of opposite type on each of 50 trials. The numbers 1 through 10 represented buyers and the numbers 11 through 20 represented sellers. To create matched pairs, the numbers 11 to 20 were randomly sampled without replacement and sequentially matched with numbers 1 through 10. In assigning reservation values, an initial string of fifty random numbers was generated from the seller's distribution, F~uniform[0,100]. These random values were then used for each seller. For each seller, the order of the values was randomized. A similar procedure was used to generate reservation values for the buyer over the discrete uniform distribution, G~uniform[0,200].

Table 4-1 outlines the design used for the experiments reported in this chapter. Focusing on the asymmetric information case (favoring the buyer), the experiments differ only in the number of stages and the sophistication/experience characteristics of subject populations. Each treatment consisted of least two sessions with the exception of the sophisticated group, which was not possible to replicate due to availability of subjects with similar characteristics.

TABLE 4-1. Two-stage Experimental Design

Treatment	n	Parameter values	Scope
Baseline*	2 groups	F~[0,100], G~[0,200], k=0.5	*20 subjects per group, 50 trials*
Inexperienced	2 groups	F~[0,100], G~[0,200], k=0.5	*20 subjects per group, 50 trials*
Sophisticated	1 group	F~[0,100], G~[0,200], k=0.5	*20 subjects per group, 25 trials*
Experienced	2 groups	F~[0,100], G~[0,200], k=0.5	*20 subjects per group, 50 trials*

*Single-stage game whereas the others are two-stages

(2) Subjects. Subjects were recruited from three distinct populations. In total, one hundred undergraduate and graduate students from the University of Arizona and twenty post-doctoral students from across the U.S. and Europe participated in a bilateral two-stage bargaining game of asymmetric and incomplete information. The first two groups ("Inexperienced") of subjects were recruited from the local undergraduate population through standard recruiting procedures while ensuring that they had no prior experience with the particular class of bargaining games being studied. The second treatment ("Sophisticated") involved similarly inexperienced players except that this group differed from the previous groups in that they all had doctoral-level training in economics. Subjects for this treatment were recruited from participants in a summer workshop on experimental economics sponsored by the International Foundation of Experimental Economics and the Economics Science Laboratory at the University of Arizona. All participants had (or were working toward) Ph.D.s in economics or related disciplines. The third ("Experienced") set of experiments used undergraduate students enrolled in a bargaining class. Two weeks prior to participating in the current two-stage study, these students participated in a single-stage bargaining experiment with payment contingent upon performance. The following week during the regularly scheduled class period, the student participants had the opportunity to openly discuss the results and the LES solution. The students were made aware of the information asymmetry and the observed effects on the LES. These same students then participated in the two-stage session the following week with the same financial incentives as in previous groups and an additional incentive that individual performance in the experiment impacted the student's course grade.

With the exception of the Sophisticated condition, subjects were paid 100 francs=$1.00 US. The mean payoff for these subjects was approximately $18.00. The mean payoff for subjects in the Sophisticated session was approximately $50.00 with 40 francs=$1.00 US. In addition, all the subjects in the Inexperienced condition received a fixed show-up fee of $5.00. Subjects in the experienced treatment received course participation credit in lieu of a show up fee. All subjects in all sessions were paid contingent on performance.

(3) Procedure. The same procedure was used for all sessions reported in this chapter. Sessions were conducted in the Enterprise Room (ER) and the Economics Science Laboratory (ESL) at the University of Arizona. Communication between subjects was strictly forbidden. With the exception of sophisticated treatment session (only 25 trials were possible in a 2 ½ hour session), each session lasted approximately two hours accomplishing 50 trials within the allotted time.

Approximately thirty subjects were recruited for twenty slots in each session. Upon arrival at the lab, the experiment supervisor paid the $5.00 show-up fee and signed extra credit participation forms.[39] The experiment supervisor then asked if anyone wished to leave instead of participating in the experiment with future payment contingent on performance (but no one did). The subjects were next asked to draw a poker chip from a bag containing 20 white numbered chips and a complementary number of red chips. Subjects drawing a numbered chip were seated at the requisite station number. Subjects

[39] Several undergraduate business courses routinely offer students enrolled in them extra credit for volunteering to participate in decision-making experiments during the semester.

drawing a colored chip were thanked and dismissed. Individuals drawing numbers 1 through 10 assumed the role of a buyer and the remaining individuals assumed the role of a seller. Once seated, subjects were given the printed instructions (see Appendix F) and allowed to read them during the first fifteen minutes of the session. Buyers sat on one side of the laboratory sellers on the other to help prevent any transfer of private information between buyers and sellers. The subjects were explicitly instructed that their bargaining partners were randomly varied from trial to trial. All fifty trials were structured in exactly the same way. At the beginning of each trial, both seller and each buyer privately received a reservation value randomly drawn with equal probability from their respective distributions. To allow between-subjects comparisons, each trader received a different permutation of the same fifty reservation values, identical to those used in the Baseline treatment.

Bargaining continued exactly as noted in Chapter II with buyer (seller) being prompted to state her offer to buy (offer to sell) for the first stage of each trial and for the second stage provided no agreement had been reached. Once all fifty trials were completed,[40] each subject was separately paid contingent on his or her performance, thanked, and dismissed.

D. Results

This section is organized as follows. First, comparisons between groups within a subject population are made (no differences) and then aggregated by condition and compared. Because there are significant differences in behavior between the different

[40] Because the sophisticated subject group took significantly longer than anticipated, only 25 two-stage trials were completed.

populations, no further aggregation is made. Second, individual data is reported for each player in each condition for stages 1 and 2, separately. Finally, aggregate analysis by stage and condition is presented followed by a brief discussion of the two-stage mechanism. The overall findings indicate that different populations reveal information about their respective reservation values during early trials of the game. However, over the course of play, subjects learn not to reveal information during stage 1. Stage 2 results are very similar to single-stage results, providing increased support for the information disparity hypothesis.

(1) Within and Between Treatment Comparisons. Data were collected from five two-stage bargaining groups. Differences due to sophistication and experience of the subjects within each treatment were significant, which prevents aggregation of the raw data. The five groups are discussed based on the characterization of the subjects within the treatments: Inexperienced, Sophisticated and Experienced.

Pairwise comparisons between the two "Inexperienced" groups, which consisted of subjects who had never before participated in a bargaining experiment, revealed no differences between buyers or sellers in either stage 1 or stage 2. The median number of agreements reached in stage 1 by buyers was 4.5 in Group 1 (ranging from 1-22) and 4.0 in Group 2 (ranging from 0-16). A pairwise *t*-test revealed no differences between groups for number of agreements reached in stage 1 (p=0.563). Similarly for stage 2, the median number of agreements reached by buyers was 22.5 in Group 1 (ranging from 8 to 28) and 25.5 in Group 2 (ranging from 10 to 29) revealing no difference (p=0.254).

No differences were observed for the sellers either. The median number of agreements reached in stage 1 by the sellers was 5 in Group 1 (ranging from 2 to 14) and 4 in

Group 2 (ranging from 0 to 11). A pairwise t-test revealed no differences between groups for number of agreements reached in stage 1 (p=0.330). Similarly for stage 2, the median number of agreements by sellers was 22 in Group 1 (ranging from 13 to 31) and 23 in Group 2 (ranging from 19 to 30) revealing no difference (p=0.218). A comparison of earnings between buyers (p=0.468) and sellers (p=0.126) separately also revealed no significant differences.

Groups 3 and 4 consisted of "Experienced" subjects who previously participated in a single-stage bargaining game. Pairwise comparison between these groups also revealed no differences during stage 1 play for either buyers (p=0.330) or sellers (p=0.357). Similarly for stage 2, neither buyers (p=0.530) nor sellers (p=0.652) demonstrated any significant differences[41].

Comparisons between the Inexperienced, Sophisticated, and Experienced treatments reveal significant differences during stages 1 and 2. Table 4-2a lists the p-values resulting from the two-sample, two-tailed t-tests for the pairwise comparisons of deals made during stage 1.

TABLE 4-2a. Treatment Comparisons by Stage 1 Agreements

		Inexperienced	Sophisticated
Buyers			
	Sophisticated	p=0.007	--
	Experienced	p=0.014	$p<0.001$
Sellers		Inexperienced	Sophisticated
	Sophisticated	$p<0.001$	--
	Experienced	p=0.008	$p<0.001$

[41] Using standard t-tests for differences, results of the single-stage game played by the Experienced subjects two weeks prior did not differ from previously reported results of similar single-stage games. Thus concluding that the subject sample drawn from the bargaining class for the Experienced treatment did not differ a priori from the typical inexperienced subjects who are normally recruited.

Although the differences are significant for buyers at a Bonferroni-corrected α=0.05, the differences for sellers are significant at α=0.01. Comparisons to the Sophisticated group only consider the first 25 trials. Table 4-2b reports the p-values for the pairwise comparisons for total deals made using the same t-tests. The only observed difference during the first block of 25 trials occurred between the Sophisticated and Experienced groups.

TABLE 4-2b Treatment Comparisons Across Stages

		Inexperienced	Sophisticated
Buyers			
	Sophisticated	p=0.242	--
	Experienced	p=0.096	p=0.024
Sellers			
		Inexperienced	Sophisticated
	Sophisticated	p<0.323	--
	Experienced	p=0.297	p=0.047

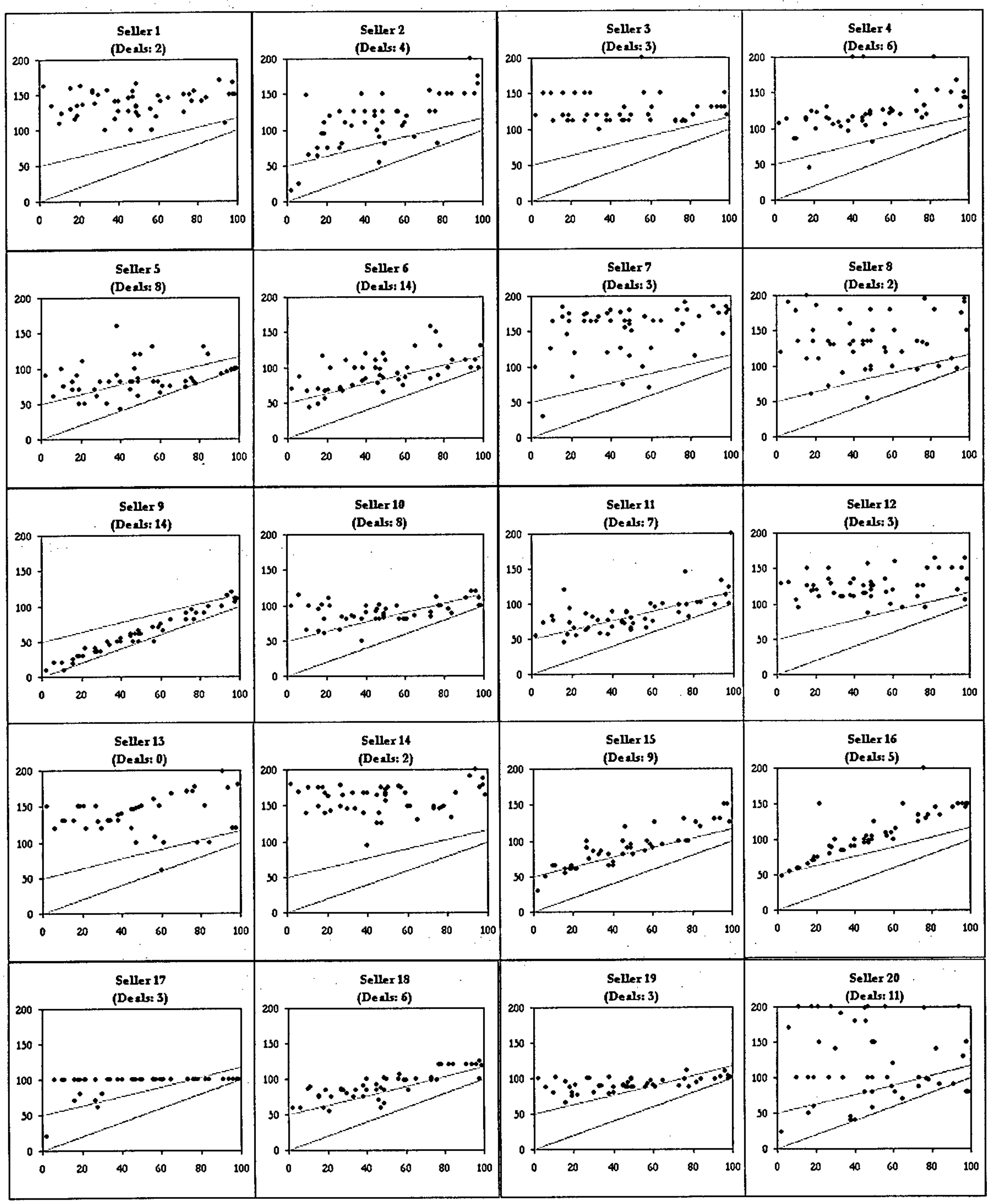
(2) Individual Data. Following from the prediction that players should reveal no information during stage 1 and adhere to the LES during stage 2, this subsection reports results for both buyers and sellers separately in stage 1 across conditions followed by similarly organized results from stage 2. On each of the Stage 1 individual scatterplots (Figures 4-2a through 4-4b), the number of deals made during stage 1 play is listed under each subject title. Likewise, on each of the Stage 2 individual scatterplots (Figures 4-5a through 4-7b), total earnings are listed under each subject title.

(a) Stage 1.

(i) Inexperienced, Buyers. Highly varied individual patterns of bidding are evident in the plots of stage 1 bids for inexperienced buyers (Figure 4-2a). Average stage 1

bids ranged from $\bar{b}_l$ =12 (Buyer 18) to $\bar{b}_l$ =87 (Buyer 6) with an overall mean of $\bar{\bar{b}}_l$ =42. Buyers 6 and 14 bid relatively honestly throughout stage 1 play but exhibited minor shaving achieving 22 and 16 deals, respectively, resulting in the lowest earning of all buyers in the treatment. Buyers 3, 4, 9, 11, 16, 18 and 20 bid considerably more aggressively resulting in far fewer stage 1 deals. Three subjects (Buyers 11, 18 and 20) did not make any deals during stage 1 while only two subjects (Buyers 3 and 4) only made a single deal each, both on Trial 2. Buyer 15's pattern of behavior is noteworthy as it is very consistent across trials closely approximating the single-stage LES with minor shaving. The remaining subjects tended to have inconsistent strategies when looking at the scatterplots of bids, but analysis of the trial-to-trial data indicates that behavior changed systematically as subjects gained more experienced during the course of the experiment. For instance, although Buyers 2, 7, 8 and 10 made 32 deals collectively during stage 1, only two of these occurred after Trial 25. Similarly for Buyers 12, 13, 17 and 19, in the second group of the Inexperienced treatment, they collectively achieved 26 deals and all but three of these occurred prior to Trial 25. Out of a total of 113 stage 1 deals, 73% occurred in the first half of the experiment. Approximately half (51.4%) of all buyer stage 1 bids were less than or equal to b=50, revealing no information about their reservation values and approximately 11% of these offers were for 1 franc. Seventeen of the twenty buyers each made one or more offers of b=1 during stage 1 bidding. Only once occurrence of a buyer bidding below his reservation value on stage 1 was observed (Buyer 8 during Trial 4) but the offer did not result in agreement. The number of agreements achieved during stage 1 is negatively correlated with final earnings (ρ=-0.804) for the buyers.

FIGURE 4-2b. Inexperienced Sellers, Stage 1

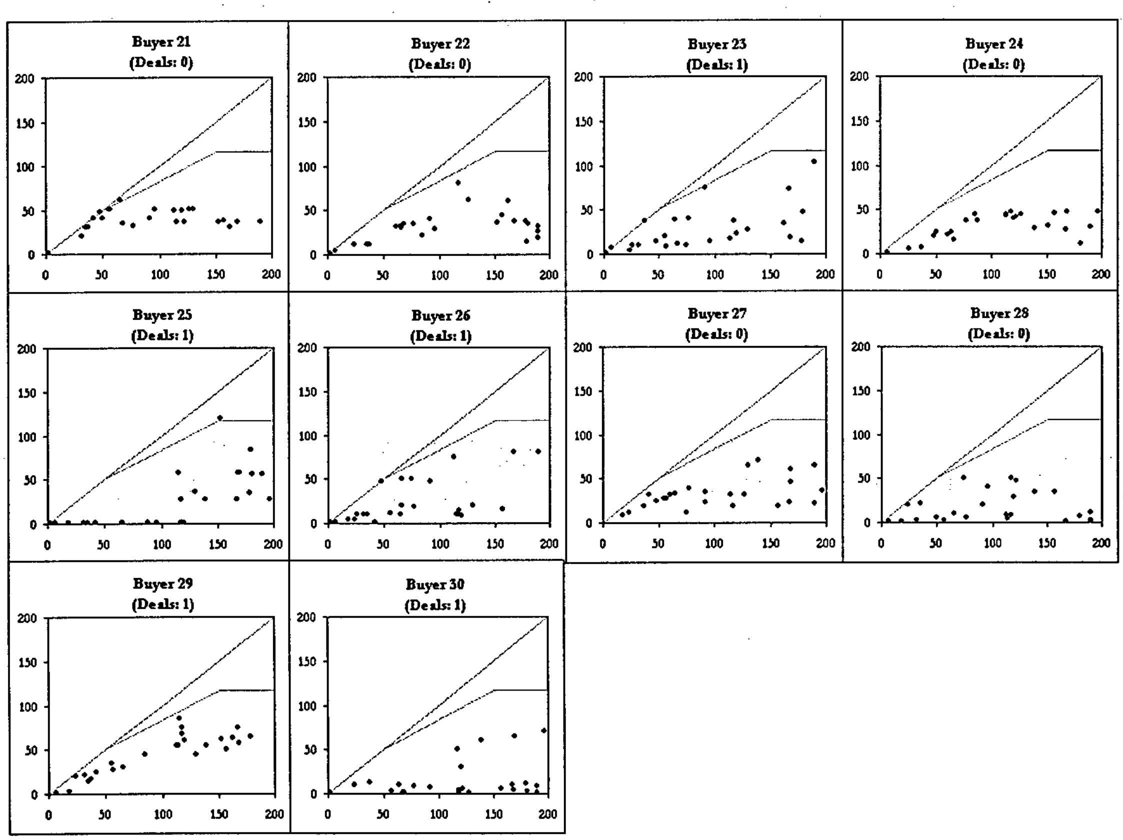


(ii) Inexperienced, Sellers. Sellers responded in kind by asking for at least s_1=100 during the first stage 64.9% of the time but only 29.8% of the offers exceeded s_1=116.67, the upper bound of the single-stage LES. Sellers 9 and 20 each made two offers below their reservation values during the first seven trials. Although Seller 9 did not reach an agreement with her $s_1 < v_s$ offers, Seller 20 did. She lost three francs on Trial 7, after which, she made no more stage 1 offers below valuation. It should be noted that on these two particular occasions, Seller 20 had reservation values of v_s=99 and v_s=98 and asked s_1=80 in both cases. Eight subjects collectively made sixteen stage 1 offers of s_1=200 and one more of s_1=225, almost half by Seller 20. Sellers 1 and 3 behaved aggressively during stage 1 by never making an offer below s_1>100. Sellers 7 and 12 each had five stage 1 asks below s_1<100. Seller 7 asked for at least $s_1 \geq 100$ consistently after Trial 12 and Seller 12 did the same consistently after Trial 4. Sellers 13 and 14 each made a single stage 1 offer below s_1<100 on Trials 37 and 50, respectively, but neither resulted in a deal. During Trial 4, Seller 17 made his only stage 1 ask other than consistently asking s_1=100 until Trial 40. Then, during the final 10 trials, he made information revealing asks 50% of the time. Conversely, Seller 5 only made ten asks greater than or equal to $s_1 \geq 100$ -- once during Trial 11 and then consistently during Trials 42-50. Seller 9 also made few asks (seven) at or above $s_1 \geq 100$ periodically between Trials 17 and 48. His behavior is noteworthy because he consistently made stage 1 asks relatively honestly with only minor shaving across trials. With the exception of two asks for high reservation values, all of Seller 9's asks lie between truth-telling and the single-stage LES. Seller 13 was the only one who did not make a deal during stage 1. Three subjects made two (Sellers 1, 8 and 14) deals and five subjects made three

(Sellers 3, 7, 12, 17 and 19). The remaining seven sellers (6, 10, 11, 15, 16, 18 and 19) made stage 1 asks consistent with (to varying degrees) the single-stage LES. Mean stage 1 asks by sellers ranged from $\overline{s_1}$ =60 (Seller 9) to $\overline{s_1}$ =159 (Seller 14) averaging $\overline{\overline{s_1}}$ =111. Although considerable, the correlation between stage 1 agreements and final earnings (ρ=-0.415) for Inexperienced sellers is about half that observed for the buyers (ρ=-0.801).

(iii) Sophisticated, Buyers. There is relatively little to say about the behavior of subjects in the Sophisticated treatment because of the extreme homogeneity, especially after the first few trials (Figure 4-3a). All subjects exhibited aggressive bidding reaching

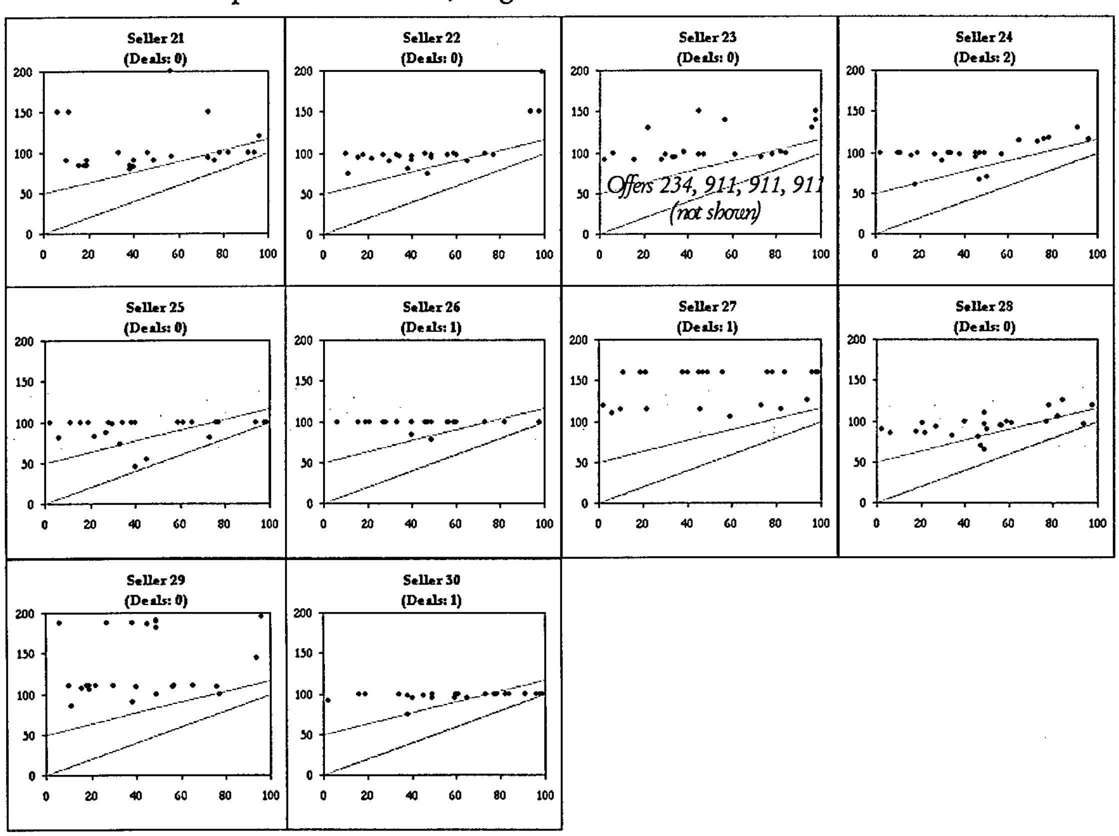
FIGURE 4-3a. Sophisticated Buyers, Stage 1



only five agreements during stage 1 play. Four of these agreements occurred on the first trial and the fifth occurred on the second trial. Only 16.4% of (41) stage 1 bids exceeded $b_1 > 50$ and all but nine of these bids occurred in the first ten trials. However, only seventeen offers of $b_1 = 1$ were made and all but four of these bids were made by Buyer 25. Only two-stage 1 offers exceeded predictions of the single-stage LES and both of these offers occurred on the first trial.

(iv) Sophisticated, Sellers. As with the buyers, subjects assigned to the seller role also demonstrated aggressive, homogeneous behavior with stage 1 asks (Figure 4-3b). However, sellers tended to be less aggressive than the buyers by making more information

FIGURE 4-3b. Sophisticated Sellers, Stage 1

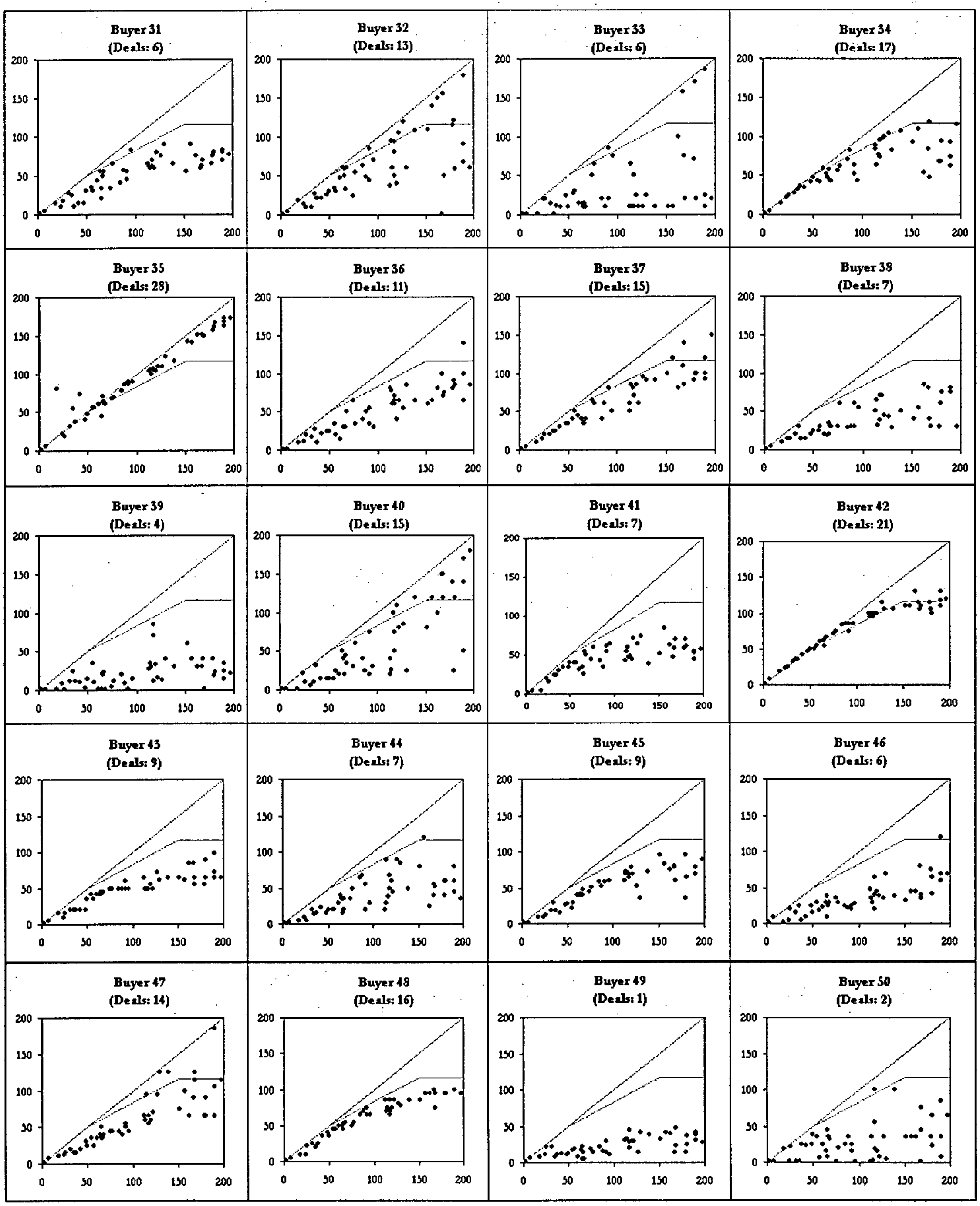


revealing offers (asking for less than $s_1<100$). Although 40.8% of stage 1 asks were below $s_1<100$, only 12% were below $s_1<90$. Most sellers submitted stage 1 asks between $90<s_1<120$ throughout the game. Seller 27 consistently asked for $s_1=160$ during Trials 10-25. Very few offers near the upper bound of the buyer's distribution were observed. Only one seller (Seller 21) made an offer of $s_1=\beta_b=200$ although Seller 22 did make a single offer of $s_1=199$. During trials 14-17, Seller 23 made offers of $s_1=911$, $s_1=234$, $s_1=911$ and $s_1=911$.[42] Despite the aggressive stage 1 behavior of sellers, 18% of the offers were equal to or less than that prescribed by the single-stage LES.

(v) Experienced, Buyers. Every buyer in the Experienced condition made at least one deal during stage 1 play (Figure 4-4a). Average stage 1 bids ranged from $\bar{b}_1=21$ (Buyer 39) to $\bar{b}_1=94$ (Buyer 35) with a mean of $\bar{\bar{b}}_1=50.5$. Buyer 40 demonstrated the most varied stage 1 behavior, evident in the definitive change in stage 1 mean bids equal to $\bar{b}_1=69$ during the first forty trials and mean stage 1 bids of $\bar{b}_1=19$ during the last 10 trials. Buyer 33 serves as a good example. She made five of her six deals during the first ten trials and did not make a stage 1 bid in excess of $b_1<50$ after Trial 22. Only Buyers 35 and 47 made offers above their reservation values (a total of six). Although Buyer 47's bid was an isolated incident where he bid $b_1=10$ with a reservation value of $v_b=7$, Buyer 35's behavior is less clear. He bid anywhere from 1 to 62 francs above his reservation value periodically

[42] Seller 23 was asked during a post-experiment presentation what message he was trying to send to his co-bargainer with the "911" offers. He stated there was no real meaning behind the offer, just an obviously high stage 1 ask.

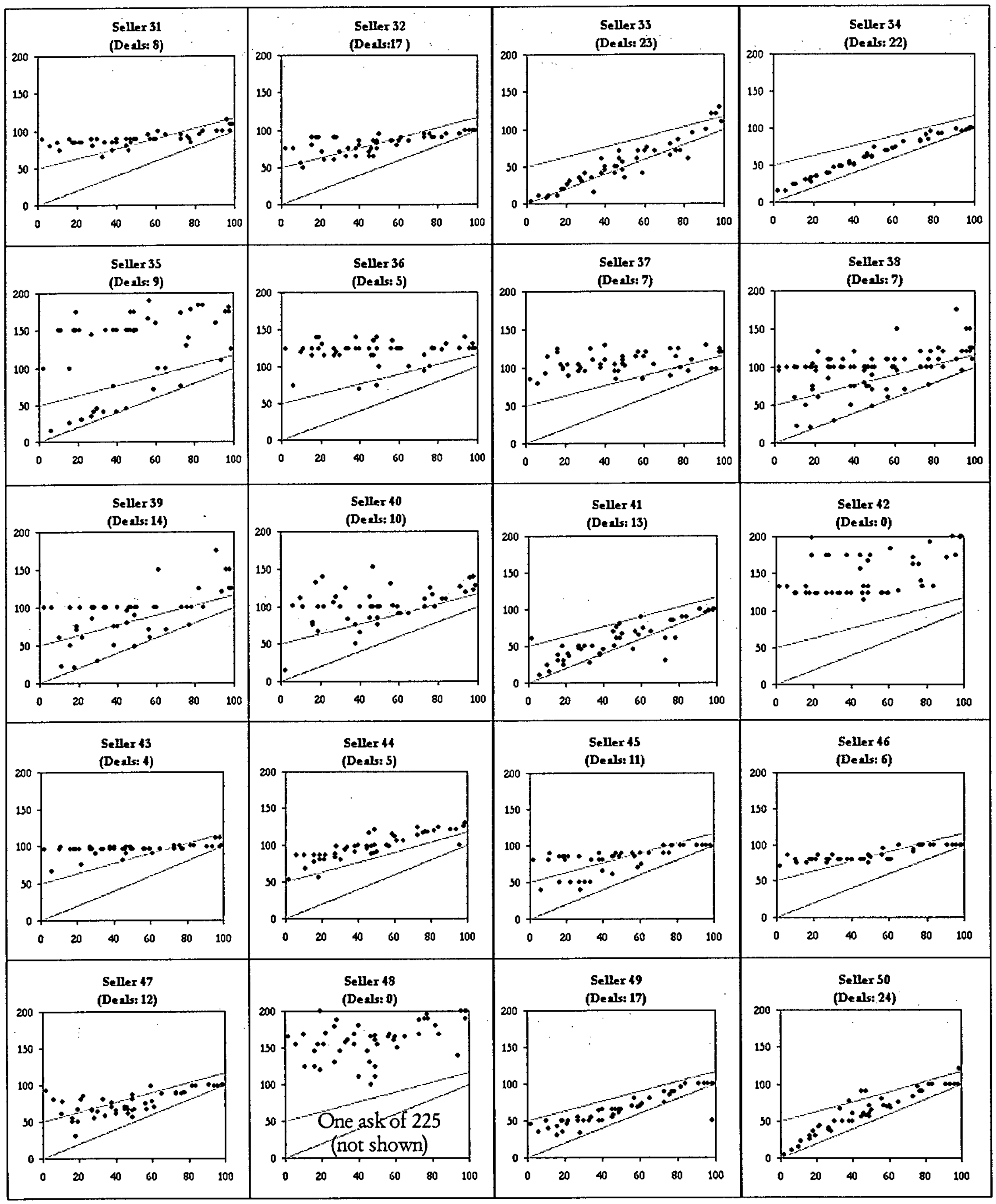
FIGURE 4-4a. Experienced Buyers, Stage 1



throughout the game for reservation values ranging from $18 \leq v_b \leq 66$. Otherwise, he followed a relatively honest bidding strategy with minor shaving during stage 1 play, and was the only Experienced buyer to do so. Buyers 42 and 48 followed strategies very close to the single-stage LES and made 21 and 16 deals in stage 1, respectively. Only Buyers 39, 49 and 50 made fewer than 5 deals. After Trial 4 having made two deals during stage 1, Buyer 39 never bid more than $b_1 \leq 50$. Buyer 49 made her sole stage 1 deal on Trial 40 with a bid of b_1=11 (the seller she was matched with asked s_1=10). Buyer 50 made two deals during the first stage and only made one offer in excess of b_1>50 during the entire game, which occurred on Trial 1 resulting in one of his two deals. He made his other deal during Trial 18 with a stage 1 bid of b_1=35. Buyers 32, 37 and 47 each made several high stage 1 bids for relatively high reservation values. The difference between the subjects is that this behavior rapidly deteriorated with Buyer 47 during the first half of the experiment, but not so with the others. Buyers 32 and 37 both continued to make high stage 1 offers throughout the course of the game. The remaining subjects tended to make stage 1 offers similar to that which has previously been observed in a single-stage game: bidding close to the single-stage LES but with considerable shaving, previously attributed to information asymmetry (see RDS and SDR). Similar to the Inexperienced buyers, stage 1 agreements and final earnings are highly negatively correlated (ρ=-0.757).

(vi) Experienced, Sellers. Sellers 42 and 48 were clearly the most aggressive during stage 1 play (Figure 4-4b). Neither player made any information-revealing stage 1 offers and consequently, neither achieved any deals during stage 1 play. Furthermore, they were also the only two subjects to ask for $s_1 \geq 200$ or more. Only once did Seller 48 ask for

FIGURE 4-4b. Experienced Sellers, Stage 1



more (s=225 during Trial 36). Three subjects (Sellers 33, 41 and 49) made offers below their reservation values during stage 1. For Seller 49, this was an isolated incident during Trial 46 with a reservation value of v_s=98. Seller 31 made losing offers during Trials 3 and 4, which resulted in deals generating losses of 2 and 18 francs, respectively. Although he made three more losing offers ranging from 6 to 48 francs below his reservations values on Trials 9, 14 and 15, none resulted in agreement. Seller 33 is more disturbing given that she made a total of twelve losing offers, including seven in a row during Trials 13-19, again on Trials 22, 23, 25, 26 and then on Trial 30. Seven of the twelve offers resulted in agreement but only two of these deals resulted in net losses. She lost 6 francs and 12 francs on Trials 17 and 18. However, previously when she submitted losing offers that resulted in an agreement, she earned 8.5, 46.5 and 41.5 francs. On the final two losing offers she made, she earned 27 and 50.5 francs, respectively. However, she ended up with the lowest earnings of all during the experiment. Sellers 33, 34, 41, 49 and 50 consistently submitted offers very close to their reservation values throughout the game during stage 1. In most all cases, the offers fell between the truth telling and single-stage LES functions. With the exception of Seller 41, all of these subjects made at least 20 deals during stage 1 play. Sellers 31, 32, 36, 37, 43, 44, 45 and 46 submitted stage 1 offers near s_1=100 (invariant of reservations value) with minor deviations, occurring mostly during early trials. Sellers asked for at least $s_1 \geq 100$ during stage 1 40.8% of the time but only 22.1% of the offers exceeded $S^*(v_s)_{max}$=116.67, the upper bound of the single-stage LES. Average stage 1 asks ranged from $\bar{s}_1$=54 (Seller 33) to $\bar{s}_1$=161 (Seller 48) with an overall mean of $\bar{\bar{s}}_1$=93.5. The mean stage 1 ask exceeded s>100 when considering only the final ten trials. Experienced buyers and both types of players in

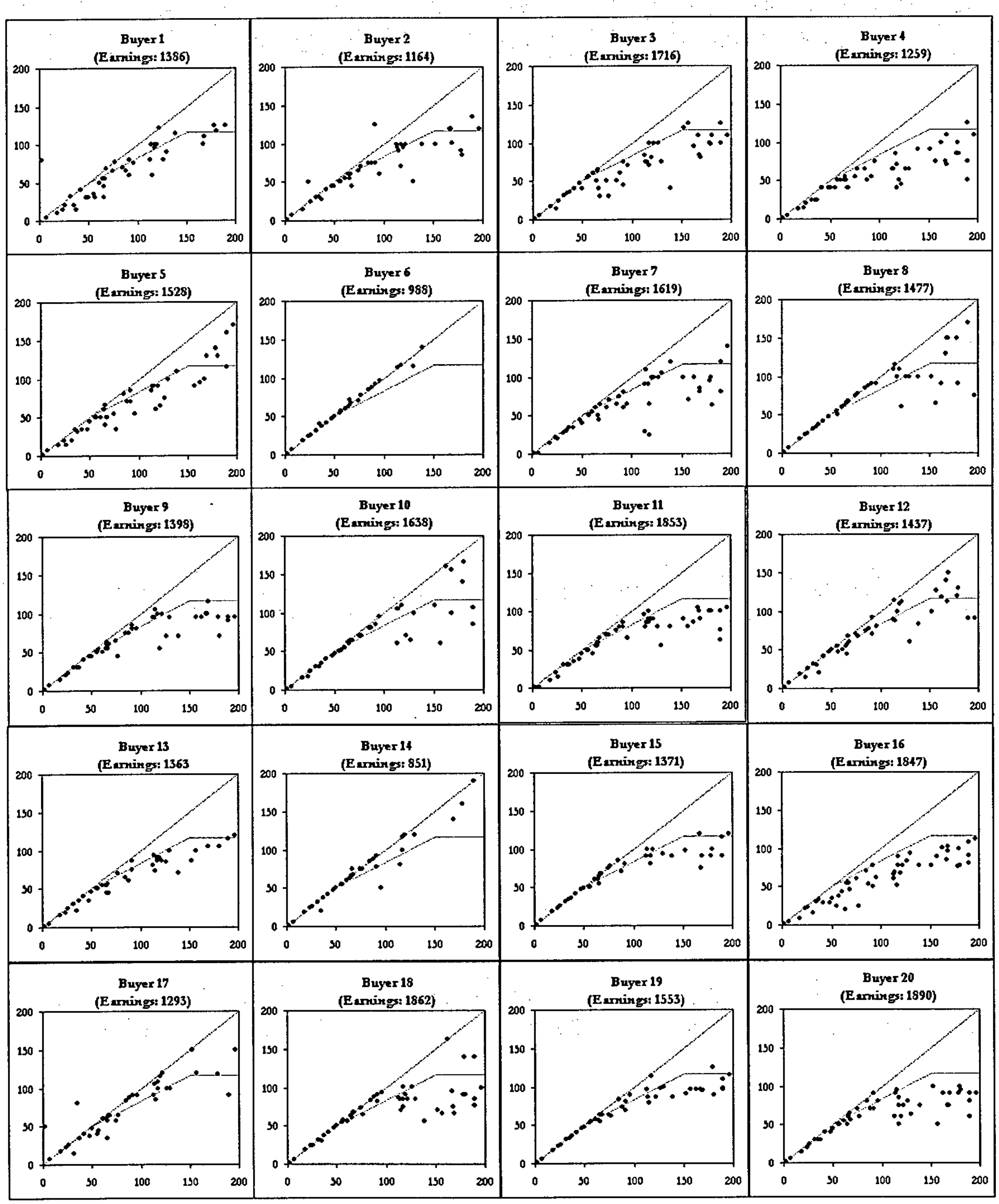
the Inexperienced treatment, there was a strong negative correlation between number of deals achieved during stage 1 and total earnings (ρ=-0.601).

(b) Stage 2.

(i) Inexperienced, Buyers. Although the single-stage LES function is not directly applicable to the two-stage experiment, it is still useful for purposes of comparison between treatments illustrating how closely results of stage 2 bidding resemble data from the Baseline game. Only two players, Buyers 6 and 14 (with some minor deviations) pursued a truthfully revealing strategy during stage 2 play (Figure 4-5a). Consequently, these two players made the most stage 1 agreements and achieved the lowest earnings of all the buyers in the experiment. On the other hand, subjects (Buyers 11, 16, 18, and 20) who made no deals during stage 1 and bid strategically (but not too aggressively) during stage 2 clearly outperformed the rest of the players.[43] Buyers 1, 3, 4, 7, 9, 13, 15, and 19 also bid closely to the single-stage LES, but earned less overall (making up to eight agreements each during stage 1). Buyers 1, 2, 6, 14, and 17 collectively made eight stage 2 offers above their reservation values. Buyer 1 did so just once on the first trial losing 78 francs and then never again. Buyer 2 (during Trials 7 and 8) and Buyer 6 (during Trials 6 and 8) each made two losing stage 2 offers resulting in no trade during the first occurrence and then in a loss the second time (losing 30 and 4 francs, respectively). As with Buyer 2, Buyer 6 neither submitted another losing offer. Buyer 14 made a single losing offer during Trial 41, bidding b_2=75 with a reservation value of v_b=67 which did not result in a deal. Buyer 17 made two

[43] These players and only these players earned more than 1800 francs.

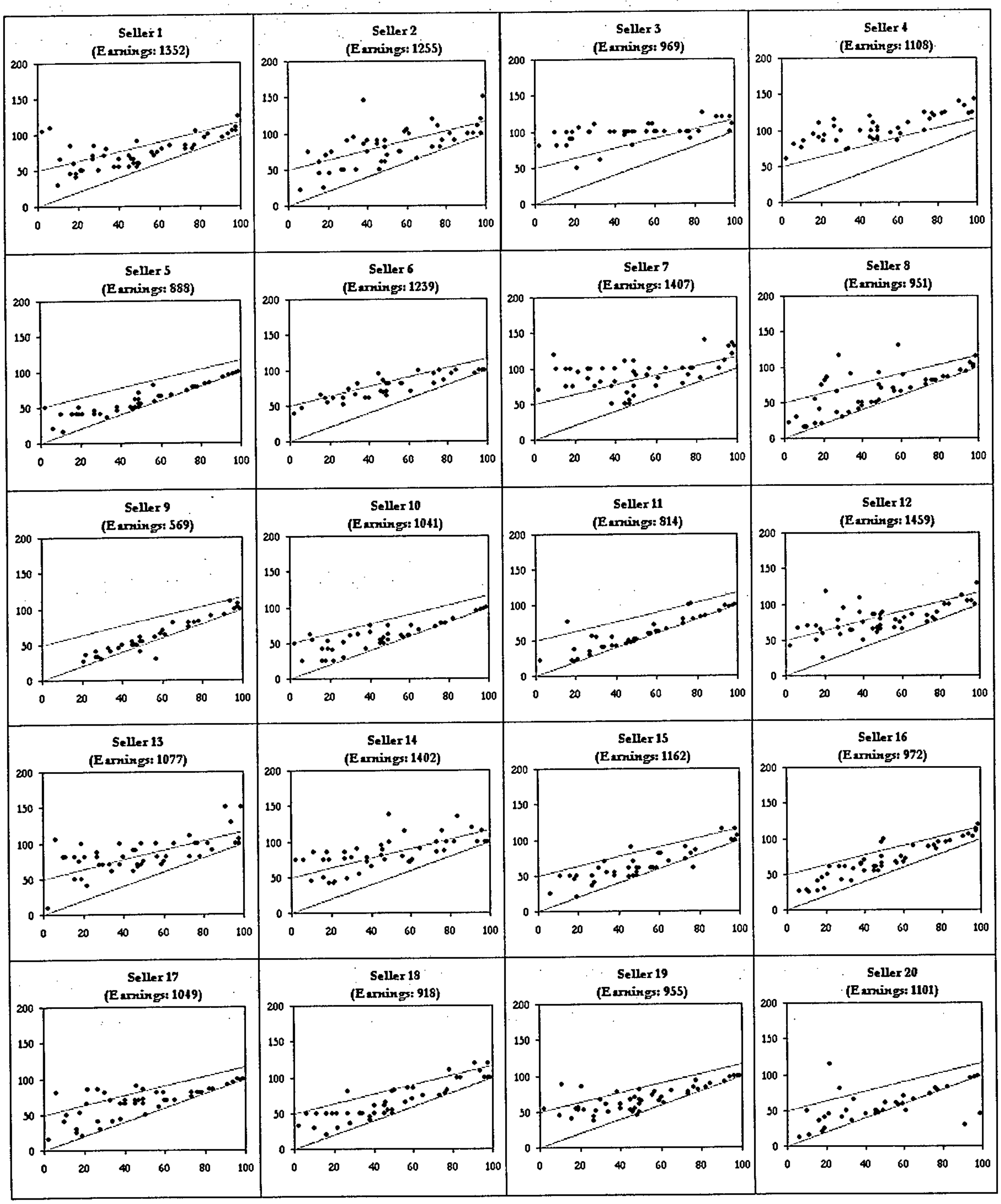
FIGURE 4-5a. Inexperienced Buyers, Stage 2



losing offers on Trials 31 and 35, each approximately 50 francs above her reservation values. Although the first offer did not result in a trade, the second did and also resulted in a loss of 20 francs. Overall, the majority of buyers demonstrated greater degrees of aggressive bidding during stage 2 compared to the single-stage LES.

(ii) Inexperienced, Sellers. The effect of the aggressive stage 2 bidding by the Inexperienced buyers had an adverse effect on the sellers, as in previously studied single-stage games with asymmetric priors. Half of the sellers (Sellers 5, 9, 10, 11 and 15-20) consistently submitted stage 2 offers between the single-stage LES and truth telling functions having been "pushed down" by the aggressive bidding of the buyers (Figure 4-5b). Sellers 3, 4, 7, 13 and 14 "stood their ground" during stage 2 and consistently asked for amounts greater than prescribed by the single-stage LES. Four sellers contributed to the nine losing offers submitted during stage 2 play. On the first trial, Seller 8 asked s_2=93 with a reservation of v_s=94 following his stage 1 ask of s_1=96, although he never asked below his reservation value again. Similarly, Seller 9 made two losing offers on Trials 4 and 5 making 32.5 francs on the latter deal (no agreement during Trial 4). Seller 15 made a single losing offer during Trial 20 and lost 17 francs. Seller 20 made four losing offers on Trials 3, 5, 7 and 11 resulting in losses totaling 115.5. Seller 2 made two second-stage offers in excess of $s_2 \geq 140$ on Trials 6 and 15, the latter resulting in a deal. With a reservation value of v_s=99, he asked for s_1=225 during the first stage and s_2=150 during the second stage reaching an agreement at a trade price of p=160. Seller 4 made an offer of s_1=s_2=142 during both stages during Trial 31 and Seller 13 made two offers of s_1=s_2=150 during mid-game play with reservation values of v_s=91 and v_s=99. Notwithstanding these exceptions, all other stage 2

FIGURE 4-5b. Inexperienced Sellers, Stage 2



offers were below $s_2 < 140$.

(iii) Sophisticated, Buyers. The similarity of behavior between Sophisticated buyers is striking. In nearly all cases, buyers bid at or slightly below the single-stage LES function (Figure 4-6a). In only two cases did a single buyer's bid exceed the maximum prescribed by the single-stage LES: $B^*(v_b)_{max}$=116.67. Buyer 25 bid b_2=120 and b_2=123 on Trials 1 and 2 reaching agreements on both. There were no cases observed of buyers bidding above their reservation values.

FIGURE 4-6a. Sophisticated Buyers, Stage 2

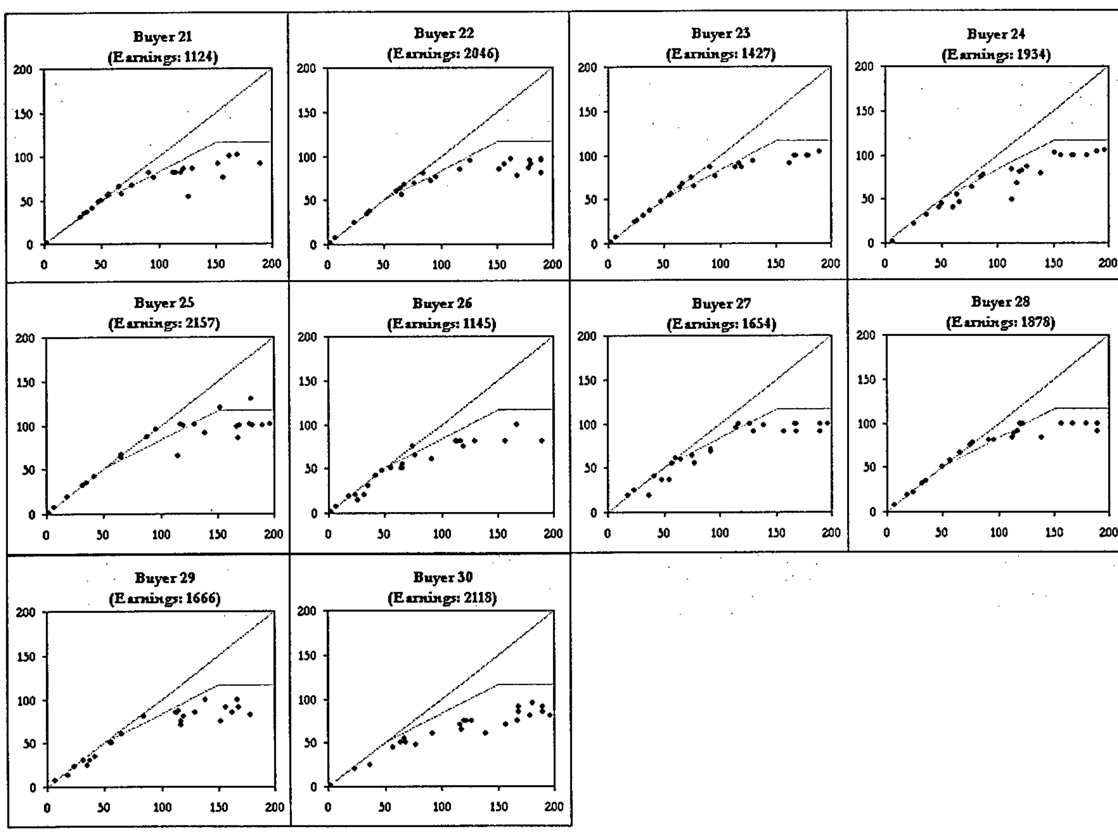
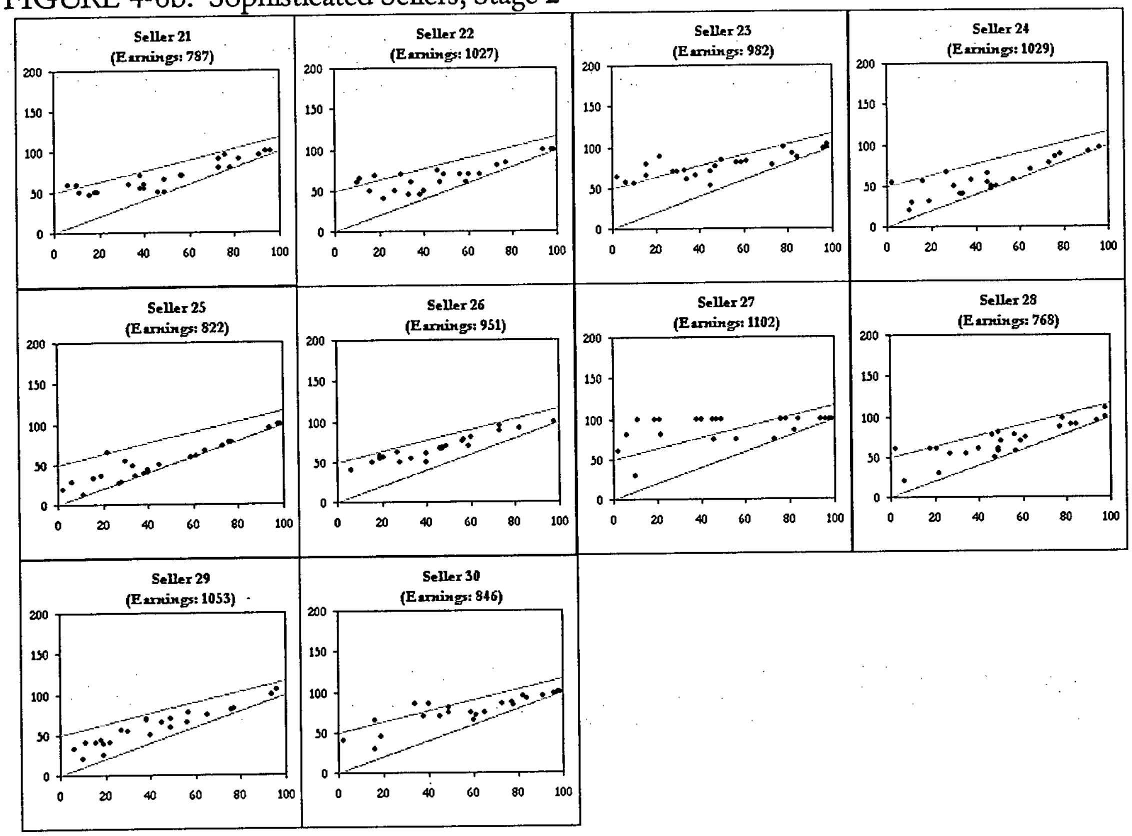


FIGURE 4-6b. Sophisticated Sellers, Stage 2



(iv) Sophisticated, Sellers. Compared to the buyers, sellers in the Sophisticated condition exhibit somewhat more variability between subjects (Figure 4-6b). Like the buyers, there are no cases of sellers submitting losing offers during either stage. Moreover, with the exception of Seller 27, the vast majority of subjects' asks lie between the single-stage LES and the truth telling function. Seller 27 provides an interesting example as she attempted to stand firm to prevent being push down by the information-advantaged buyers. Although she made fewer deals than most of the other sellers (e.g. 11 compared to Seller 22 who reached 17 agreements) , she earned the most out of any seller in the group.

(v) Experienced, Buyers. Similar to the Inexperienced condition, eight subjects (Buyers 31, 36, 37, 38, 41, 43, 45 and 47) closely approximated the single-stage LES during stage 2 play (Figure 4-7a). At the other extreme, three subjects (Buyers 34, 35 and 42) tended toward truthful revelation with their second stage bids. Although Buyers 34 and 42 tended to shave for the highest reservation values, Buyer 35 submitted seven losing stage 2 offers, some significantly above (60 to 87 francs) his reservation value. This behavior persisted from Trial 4 through Trial 37 occurring seven times and accounted for total losses of 236 francs. The reason for this behavior is not apparent. Buyers 36, 37, 40, 44 and 46 also submitted stage 2 offers above their valuations but only lost 45.5 francs over fourteen decisions.[44] In these cases, once a loss was realized, the practice of bidding above value immediately ceased. Only seven bids above b_2>140 were observed, all associated with reservation values above v_b>150.

(vi) Experienced, Sellers. There were more losing asks made by Experienced sellers during stage 2 than with Inexperienced or Sophisticated sellers --a total of thirty in all (Figure 4-7b). Although five sellers made losing offers (Sellers 33, 34, 35, 41, and 50), 87% were made by two subjects: Seller 33 and Seller 41. Although profiting by 4.5 francs on Trial 6 (his second losing offer), Seller 33 continued to post losses between Trials 6 and 49 nineteen times. Seller 41, on the other hand, lost 248.5 francs during seven of the first fifteen trials but eventually adapted his strategy thereafter making no more losing offers. Eleven subjects (Sellers 31, 32, 37, 38, 39, 43-48) consistently submitted stage 2 offers

[44] 35.5 lost in a single deal by Buyer 46.

FIGURE 4-7a. Experienced Buyers, Stage 2

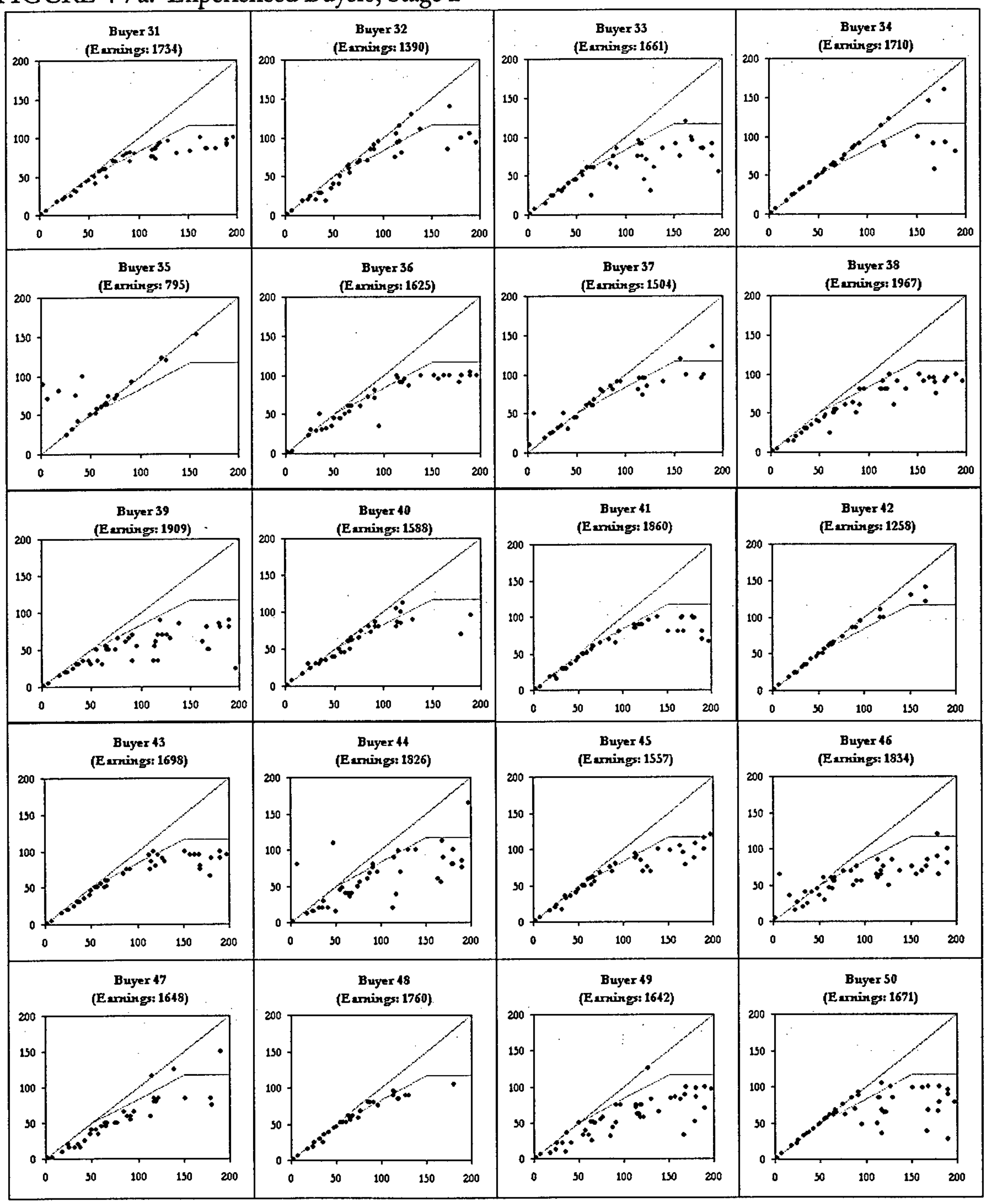
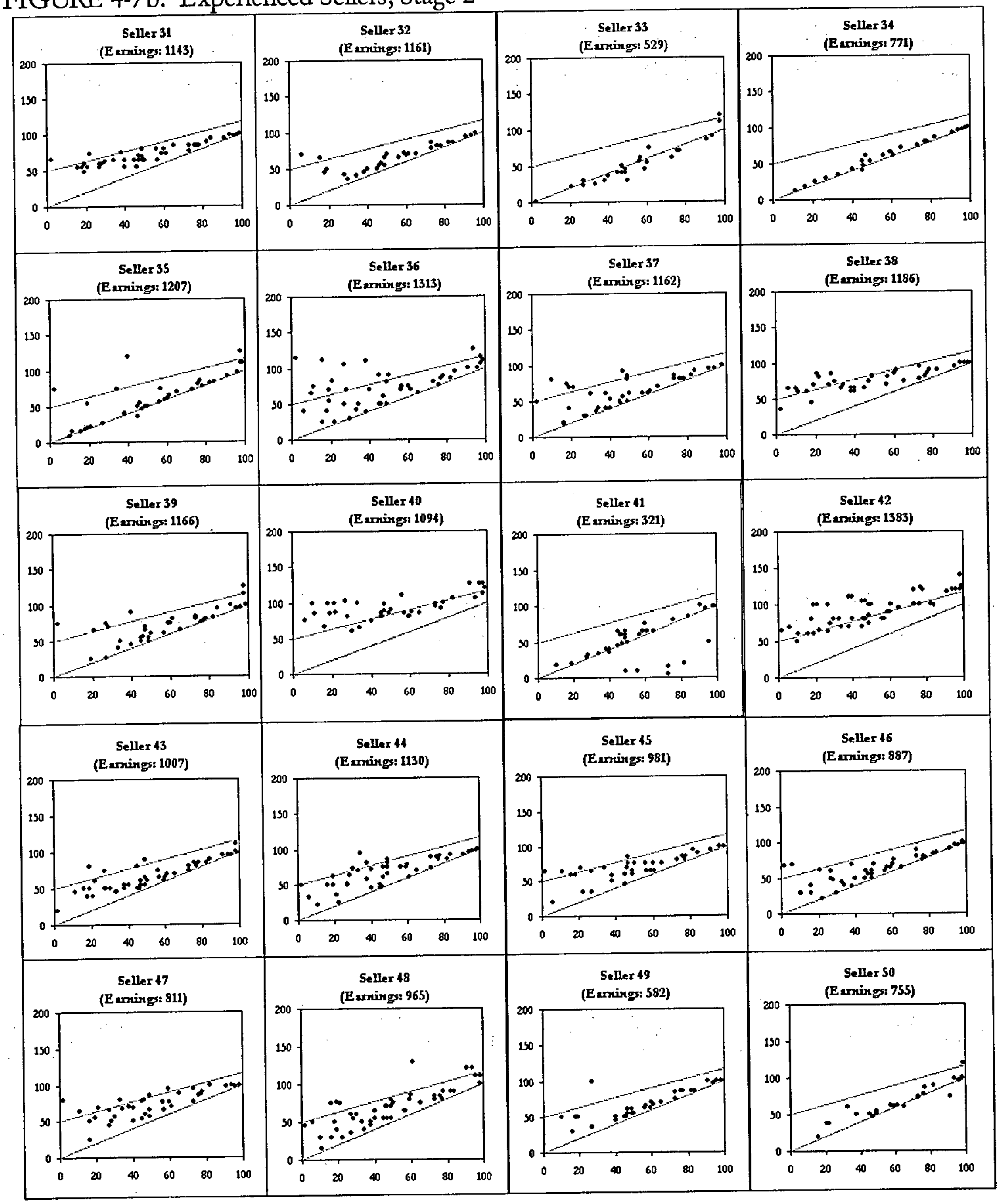


FIGURE 4-7b. Experienced Sellers, Stage 2



between the single-stage LES and the truth telling functions. Sellers 40 and 42 were more aggressive and made most of their offers near or above the single-stage LES. For low reservation values, both sellers tended to ask near s_2=100 and earned more than all but one of the other sellers, (Seller 36) who although asked below the single-stage LES for most offers, asked well above the LES line for his lowest reservation value draws "going for the kill." Note that of the three subjects (Sellers 36, 40 and 42) who made the most aggressive offers, two (Sellers 36 and 42) made the fewest stage 1 deals (5 and 0 deals respectively). Seller 40 behaved quite similarly to Sellers 36 and 42, but also made ten agreements in stage 1 and consequently earned the least. Five subjects (Sellers 33, 34, 41, 49 and 50) demonstrated very passive offer strategies during stage 2 with most of their offers lying on or near (both above and below) the truth telling function. These particular subjects accounted for nearly half (46.8%) of all stage 1 agreements but only 15.1% of the surplus afforded the sellers.

(3) Aggregate Results. Summarizing the individual results across player roles and conditions by stage, both buyers and sellers across treatments exhibited significant differences between stage 1 and stage 2 offers. During stage 1, there was considerable variation between individuals within condition for the Inexperienced and Experienced populations while Sophisticated players exhibited very little variation in comparison. Stage 2 observed offers are similar to previous studies of the single-stage mechanism with asymmetric common priors providing additional support for the information disparity hypothesis.

Differences between stage 1 and stage 2 offers are apparent in Table 4-3, which categorizes bids and asks as either "honest" (within five francs of the reservation value) or "strategic" (greater than 5 francs) across all fifty trials for each player. Although there were notable differences between the treatments, the primary effect was that the proportion of honest to strategic offers increased considerably from stage 1 to stage 2. Buyers made 6-10% honest offers during stage 1 which more than tripled in the second stage. Sellers demonstrated a similar pattern. The average proportion of honest offers[45] for buyers was 20.8% and for sellers, 19.6%. Comparing these results to the Baseline game yields mixed findings. Sellers in the Baseline single-stage treatment made honest asks 17.5% of the time, compared to 19.6% for sellers in the two-stage condition--a difference of only 2%. On the other hand, buyers in the baseline condition posted honest offers nearly a third of the time with this proportion dropping to a fifth in the two-stage condition. The Experienced subjects tended to make nearly twice the number of honest stage 1 offers compared to the

TABLE 4-3. Percentage of Offer Type by Condition

	Stage 1		*Stage 2*	
	Honest	*Strategic*	*Honest*	*Strategic*
Buyers				
Single-Stage	--	--	30.3%	69.7%
Sophisticated	6.0%	94.0%	32.2%	67.8%
Inexperienced	4.7%	95.3%	35.8%	64.2%
Experienced	9.6%	90.4%	29.0%	71.0%
Sellers				
Single-Stage	--	--	17.5%	82.5%
Sophisticated	4.0%	96.0%	24.5%	75.5%
Inexperienced	5.3%	94.7%	30.6%	69.4%
Experienced	8.4%	91.6%	36.8%	63.2%

[45] Considering all offers made in stages 1 and 2.

Sophisticated or Inexperienced subjects. During stage 2, the differences aren't as clear. Experienced sellers continued to make more honest stage 2 offers than the other conditions while Experienced buyers made the fewest honest offers. The difference between buyers in the second stage is relatively stable across conditions and quite similar to the single-stage game. However, seller behavior was considerably more varied during stage 2 and notably more cooperative than the Baseline treatment.

Table 4-4 reports results from mean stage 1 offers of the two-stage game. The Sophisticated players were clearly the most aggressive during stage 1 play yielding the lowest stage 1 bids and highest stage 1 asks. Experienced players exhibited the least aggressive offers with the lowest mean ask and the highest mean bid. Mean stage 1 offers were computed across the first forty trials for the Inexperienced and Experienced conditions and the first fifteen trials for the Sophisticated conditions and compared to mean stage 1 offers during the final ten trials of each condition. The results indicate that buyers in all conditions learned to make increasingly lower stage 1 bids while sellers learned to make increasingly higher stage 1 asks.

TABLE 4-4. Mean Stage 1 Offers by Condition

Buyers	Sophisticated	Inexperienced	Experienced
Min	16	12	21
Mean (across trials except final 10)	29	42	50
Mean (final 10 trials only)	23	29	40
Max	44	87	94
Sellers	**Sophisticated**	**Inexperienced**	**Experienced**
Min	92	60	54
Mean (across trials except final 10)	118	111	93
Mean (final 10 trials only)	127	122	100
Max	210	159	161

Trial-to-trial changes of stage 1 behavior are shown in Figure 4-8. The three-panel graph shows for each two-stage condition separately the running average (in steps of five) of stage 1 offers over the course of the experiment. As previously noted, buyers revealed no useful information by offering $b_1 \leq 50$ or less on stage 1 and sellers reveal nothing by offering more than $s_1 > 116$. In the Sophisticated condition, buyers immediately started out with mean bids less than $\overline{b_1} < 50$, and sellers' mean asks quickly increased to well above $\overline{s_1} > 100$ by Trial 7 and above $\overline{s_1} > 117$ by Trial 15. Buyers in the Inexperienced condition also recognized the value of not revealing information immediately similar to the Sophisticated buyers. However, the Inexperienced sellers made significantly lower, less aggressive stage 1 offers and continued to reveal information about their reservation value to the buyers throughout the course of the experiment, never breaking the $s_1 = 100$ barrier. Experienced buyers exhibited a much less aggressive stage 1 starting posture revealing information through the first half of the experiment, but eventually converged to mean bids below $\overline{b_1} < 50$ during latter trials. This less aggressive behavior by the buyers gave rise to the sellers' more aggressive behavior (in comparison to the Inexperienced condition). Unlike the Inexperienced sellers, the Experienced sellers eventually approached mean stage 1 asks of $\overline{s_1} = 100$. With sufficient experience and understanding of the game, subjects in both the Sophisticated and Experienced treatments converged to nonrevealing strategies yielding no information during stage 1 play.

FIGURE 4-8. Running Average of Stage 1 Offers by Condition

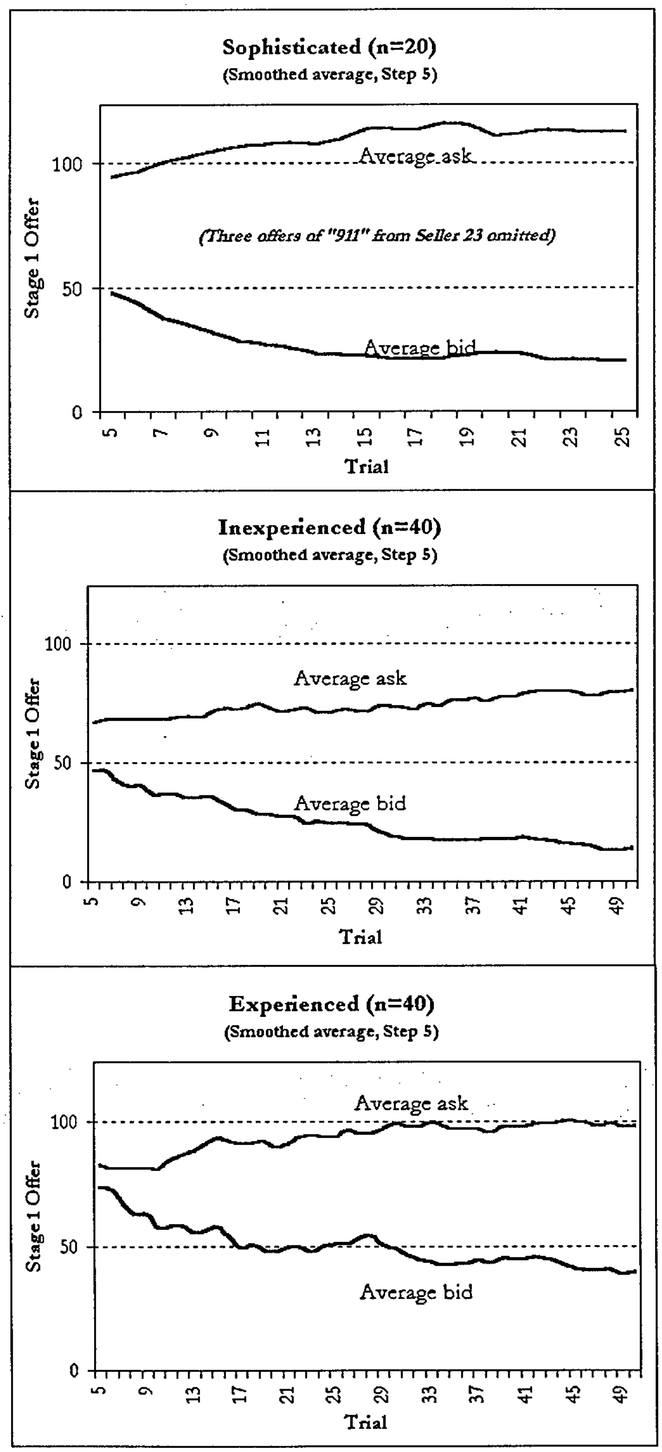


Table 4-5 reports results of stage 1 deals. Sophisticated players only made five agreements, all of which occurred in the first two trials. One-fifth of all deals made in the Inexperienced condition were the result of stage 1 agreements and this percentage increased to 35.9% in the Experienced condition. However, consistent with Figure 4-8, the change in behavior over time illustrates that players learned that stage 1 agreements were not in their best interests, and for many the number of stage 1 agreements reached declined with experience.

TABLE 4-5. Stage 1 Agreements

	Sophisticated	Inexperienced	Experienced
Across all trials			
Total deals achieved	131	561	596
Number of Stage 1 deals	5	113	214
Proportion of Stage 1 to Total deals	3.8%	20.1%	35.9%
Average deals per trial	5.2	5.6	6.0
Last 20 trials			
Total deals achieved	100	227	247
Number of Stage 1 deals	0	26	55
Proportion of Stage 1 to Total deals	0%	11.5%	22.3%
Average deals per trial	5.0	5.7	6.2

The lower panel of Table 4-5 reports analysis of the last twenty trials for all three two-stage conditions. The percentage of deals made during stage 1 declined from 3.8% to zero in the Sophisticated condition. The Inexperienced condition exhibited the largest drop from 20.1% to 11.5%, nearly a 50% reduction. A similar pattern was observed in the Experienced condition with stage 1 deals falling from 35.9% to 22.3% in later trials.

Although the decrease was significant, nearly one out of four stage 1 deals persisted due to a handful of players who continually made relatively truthful offers. Across trials, the average number of deals per trial remained stable between 5.0 and 6.2 with Experienced players achieving the largest averages.

Differences in the total number of agreements across stages compared to the single-stage game are not significant for either buyers or sellers. Table 4-6 shows that the number of agreements in the Inexperienced and Experienced treatments increased slightly from 26.9 in the Baseline single-stage condition to 28.1 and 29.8, respectively. Because the Sophisticated condition only consisted of 25 trials, it can only be compared directly to the results of the first 25 trials of the other conditions. The overall average number of deals per subject during the 25 trials of the Sophisticated group was 13.1 whereas the first block of 25 trials of both the Inexperienced and Experienced conditions yielded averages of 13.9 and 14.8, respectively. Both of these averages exceeded the single-stage Baseline average of 13.8 deals. Sophisticated players made fewer deals on average than players in the other conditions, although differences were very small and not significant.

As discussed previously, the single-stage LES provides an appropriate equilibrium to which stage 2 offers can be compared. Given the asymmetric common priors of F~uniform[0,100] and G~uniform[0,200], the LES for the seller has a y-intercept of 50 and a slope of $^2/_3$. The buyer's function is piece-wise linear in three distinct sections:

TABLE 4-6. Total Deals (Stages 1 and 2) Across Trials

	Baseline		Inexperienced		Sophisticated	Experienced	
Buyers	29	26	31	29	8	27	29
	19	29	26	27	13	27	29
	33	27	29	29	13	29	28
	34	25	18	26	14	34	28
	27	31	29	29	18	38	30
	26	26	30	28	11	31	30
	25	36	30	34	13	35	30
	18	30	29	29	15	27	31
	23	25	22	30	13	26	25
	24	25	29	27	13	32	30
Sellers	25	25	27	26	9	25	35
	19	27	31	30	17	34	25
	31	27	16	20	11	36	27
	24	27	19	25	15	32	30
	22	33	30	36	14	38	29
	21	26	27	26	13	30	30
	23	31	25	26	12	30	23
	29	34	33	32	13	28	31
	34	20	31	26	15	30	24
	29	30	34	41	12	23	36
Mean (Trials 1-25)	13.8		13.9		13.1	14.8	
Mean (Trials 1-50)	26.9		28.1		--	29.8	

slope of 1.0 from the origin for reservation values up to $v_b<50$, slope of $^2/_3$ between $50\leq v_b\leq 150$, and then a slope of zero for all reservation values greater than $v_b>150$.

Simple linear regression was used to model the sellers' offers on reservation values. For the buyers, however, given the piece-wise nature of the LES, a modified technique of spline regression is implemented. This technique uses ordinary least squares to find the piece-wise linear function of best fit by vertically adjusting the "knots" joining the segments at the predicted reservation values of $v_b=50$ and $v_b=150$ while simultaneously adjusting the slopes of the three line segments.

Table 4-7a reports the spline regression results for the first block (25 trials per block) in each of the conditions and Table 4-7b reports similar results for the second block of trials. The combined results are reported for all fifty trials and each conditions in Table 4-7c. Buyers in the Sophisticated condition tended to bid aggressively for low reservation values even though the LES predicted truthful bidding in this range. Two bids of b_2=1 were made during stage 2 for reservation values of v_b=18 and v_b=32 which pulled the intercept of first segment of the regression line down to –3.4. The slope of 1.09 was an artifact of these two outliers as in no case did any buyer bid more than his value in the condition. All other observed slopes for v_b<50 were less than or very near 1.0 as predicted. None of the intercepts were significant. For the mid-range offers (50≤v_b≤150), all slopes were significantly less than $^2/_3$ and also less than that observed in the Baseline condition. This indicated that behavior in the second stage was more aggressive than in the single-stage game. Only the most aggressive subjects self-selected themselves as players in stage 2 since less aggressive players often reached a deal during stage 1. Thus, the smaller slopes are consistent with the inherent bias in stage 2 play. For the upper range (v_b>150) the slope for the Inexperienced condition was not significant and therefore not statistically different than zero, precisely as predicted by the equilibrium. The Sophisticated buyers' slope was (surprisingly) significantly different from zero, but nevertheless very near zero at –0.03. Experienced buyers also had a negative slope for the upper range, which was also significant at p<0.001. During the second block, all slopes in the lower and middle ranges approached the equilibrium. The slopes for the upper range converged to the equilibrium for the Baseline condition. However, for both Inexperienced and Experienced subjects, slopes

TABLE 4-7a. Spline Regression Results, Buyers, Block 1: Trials 1-25 (Stage 2 only)[46]

	$v_b < 50$		$50 \leq v_b \leq 150$		$150 < v_b$		
	Slope	Intercept	Slope	Spline knot	Slope	Spline knot	Adj. R^2
LES	1.00	0.0	0.67	50.0	0.00	116.7	
Single Stage	0.90**	2.7	0.57**	47.9	0.25*	104.6	0.75
Sophisticated	1.09**	-3.4	0.44**	51.2	-0.03**	95.6	0.90
Inexperienced	0.98**	-0.1	0.48**	48.7	0.28	96.9	0.76
Experienced	0.82**	6.9	0.46**	47.8	-0.12**	93.7	0.66
Truth-telling	1.00	0.0	1.00	50.0	1.00	150.0	

*$p<0.01$ and **$p<0.001$ of being different from zero.

TABLE 4-7b. Spline Regression Results, Buyers, Block 2: Trials 26-50 (Stage 2 only)

	$v_b < 50$		$50 \leq v_b \leq 150$		$150 < v_b$		
	Slope	Intercept	Slope	Spline knot	Slope	Spline knot	Adj. R^2
LES	1.00	0.0	0.67	50.0	0.00	116.7	
Single Stage	1.01**	-1.2	0.60**	49.3	0.09**	109.0	0.77
Sophisticated	--	--	--	--	--	--	--
Inexperienced	0.99**	-1.1**	0.59**	48.6	-0.07**	107.4	0.76
Experienced	0.94**	-0.6	0.55**	46.6	-0.34**	101.7	0.75
Truth-telling	1.00	0.0	1.00	50.0	1.00	150.0	

*$p<0.01$ and **$p<0.001$ of being different from zero.

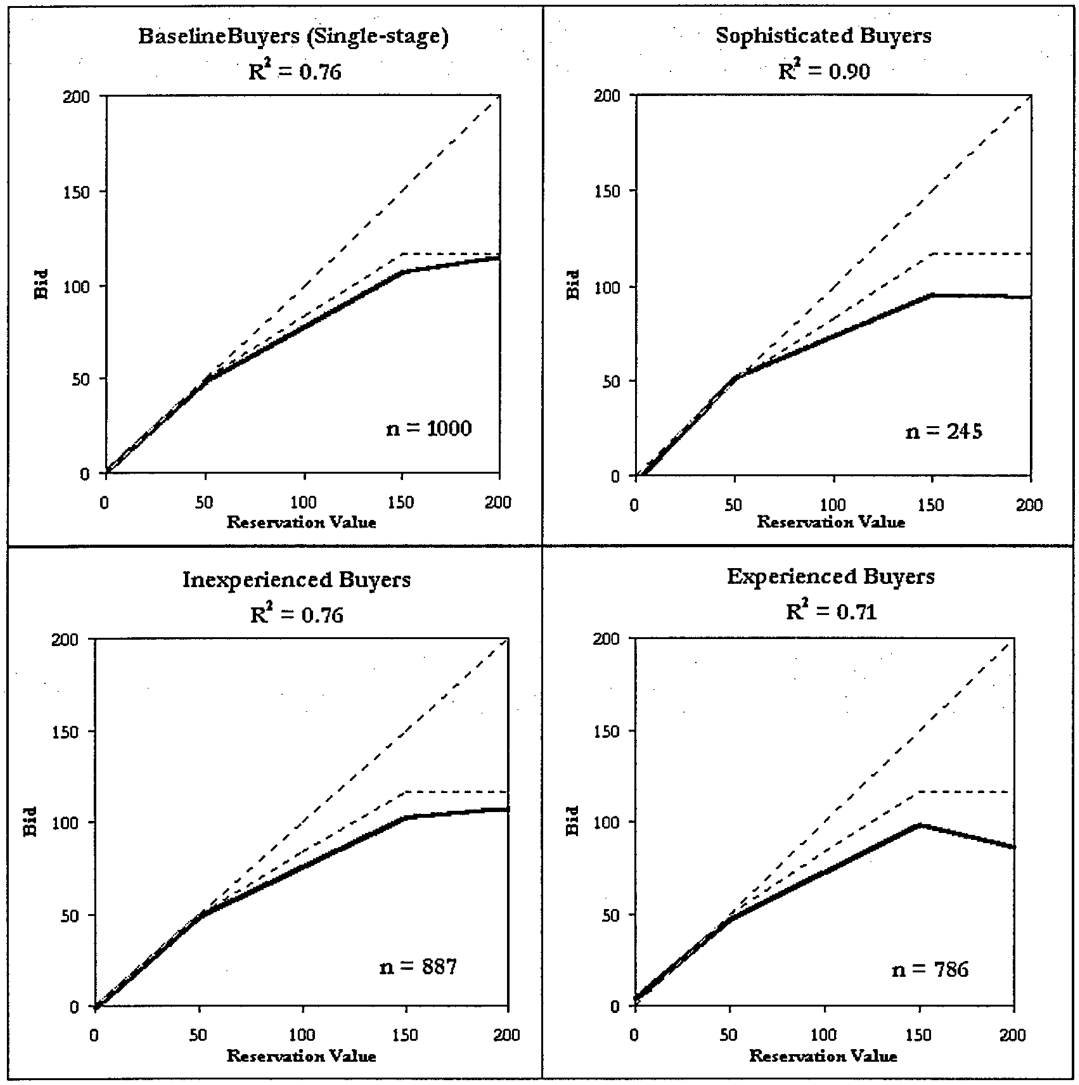
TABLE 4-7c. Spline Regression Results, Buyers, Across Blocks: Trials 1-50 (Stage 2 only)

	$v_b < 50$		$50 \leq v_b \leq 150$		$150 < v_b$		
	Slope	Intercept	Slope	Spline knot	Slope	Spline knot	Adj. R^2
LES	1.00	0.0	0.67	50.0	0.00	116.7	
Single Stage	0.96	1.0	0.58	48.8	0.17	106.6	0.76
Sophisticated	1.09	-3.4	0.44	51.2	-0.03	95.6	0.90
Inexperienced	0.99	-0.6	0.53	48.8	0.09	102.2	0.76
Experienced	0.87	3.9	0.51	47.2	-0.24	98.0	0.71
Truth-telling	1.00	0.0	1.00	50.0	1.00	150.0	

Note: All reported slopes are significantly different than zero at $p<0.001$ at $\alpha=0.05$; however, none of the intercepts are significant.

[46] Stage 2 results cannot be directly compared to the single-stage LES since stage 2 bids are conditional on stage 1 play (requiring subgame perfect equilibrium analysis). If and only if no information is revealed during stage 1 play can stage 2 results be directly compared to the single stage LES. Such was the case for Sophisticated players but not so for either the Inexperienced or Experienced players.

FIGURE 4-9. Best Fitting OLS Stage 2 Bid Functions, Buyers



became increasingly negative falling by 0.35 and 0.22 respectively. Figure 4-9 graphically depicts the spline function across trials as documented in Table 4-7c. Stage 2 bidding in the Inexperienced and Sophisticated conditions was very similar to the single-stage Baseline condition. The only notable difference occurred for the highest values in the Experienced condition. The spline functions produced coefficients of variation ranging between R^2=0.71 and R^2=0.90 indicating very good static model fit.

Table 4-8 reports regression results for the sellers by blocks and across all trials for each condition separately. The intercepts for the Baseline and all two-stage conditions were below the LES predicted value of 50. However, the Inexperienced sellers reached 47.5. The slope for the Baseline condition was slightly greater than predicted which compensated for the lower intercept of 32.6. The slopes for all other conditions were less than 0.67. During the second block, directional changes between conditions were inconsistent. The Baseline sellers' slope slightly decreased while the intercept increased compensating for the change. The slope for the Inexperienced sellers increased significantly from 0.55 to 0.65 while the intercept decreased from 47.5 to 40.8 The Experienced sellers exhibited very little change in either the slope or intercept between blocks.

TABLE 4-8. Regression Results, Sellers (Stage 2 only)

	Block1: Trials 1-25			Block 2: Trials 26-50			Trials 1-50		
	Slope	Intercept	R^2	Slope	Intercept	R^2	Slope	Intercept	R^2
LES	0.67	50.0		0.67	50.0		0.67	50.0	
Single Stage	0.74	32.6	0.60	0.70	38.0	0.20	0.72	35.2	0.32
Sophisticated	0.59	40.1	0.58	--	--	--	0.59	40.1	0.58
Inexperienced	0.55	47.5	0.36	0.65	40.8	0.426	0.60	44.0	0.39
Experienced	0.62	37.3	0.44	0.60	38.3	0.453	0.61	37.8	0.45
Truth-telling	1.00	0.0		1.00	0.0		1.00	0.0	

Note: All reported statistics are significant at $p < 0.001$ at $\alpha = 0.05$

Figure 4-9 graphs the results across all fifty trials (25 for the Sophisticated group) for stage 2 asks. The R^2 values are not as impressive as that of the buyers ranging from 0.32 for the Baseline sellers to 0.58 for the Sophisticated sellers. All two-stage sellers' regression functions approached truth telling with increasing reservation values, although this effect was most pronounced with the Sophisticated and Experienced sellers.

FIGURE 4-10. Best Fitting OLS Stage 2 Ask Functions, Sellers

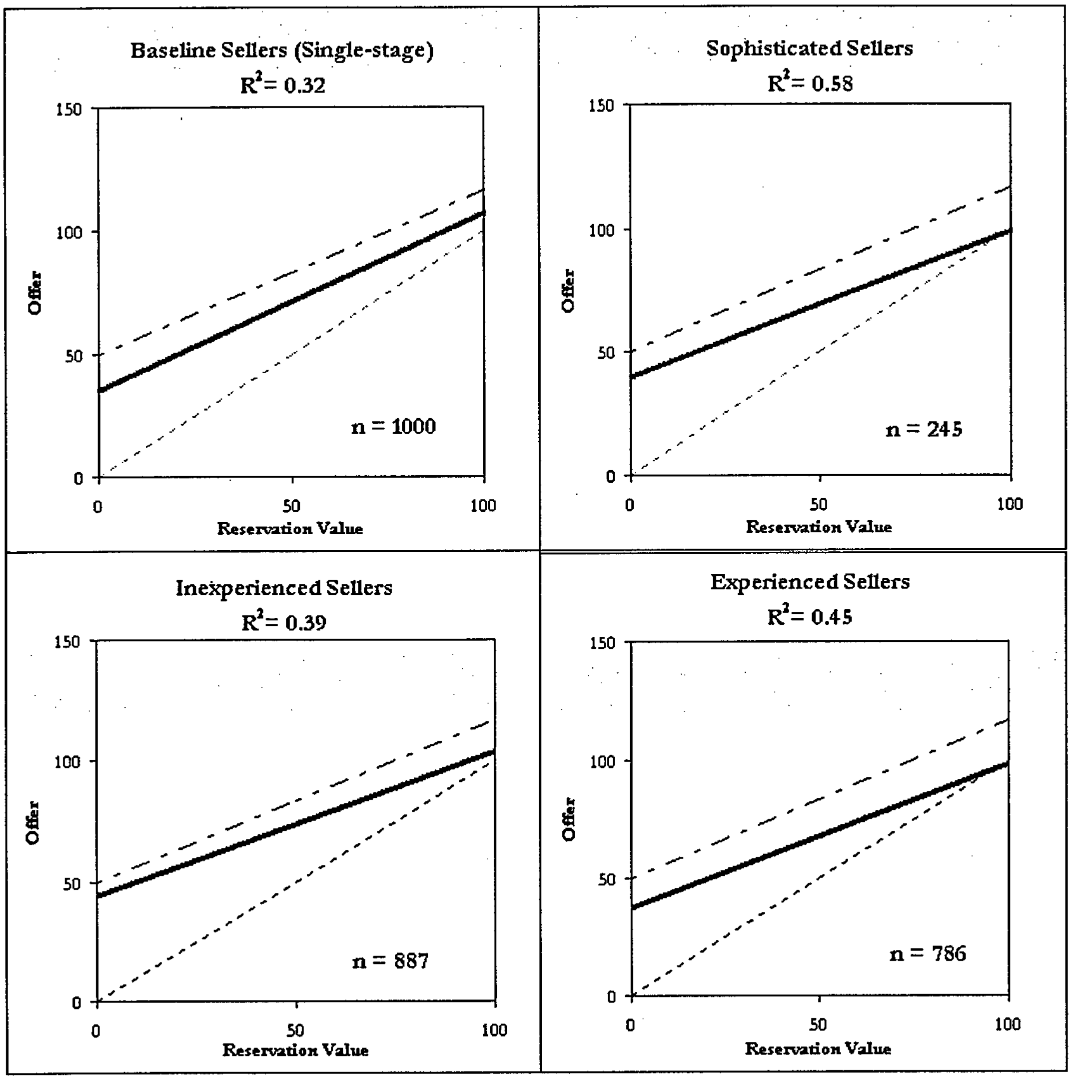


Table 4-9 reports individual earnings for all subjects in the study. Maximum earnings achievable through bilateral truthful bidding for both 25 trials (for purposed of comparison with the Sophisticated condition) and 50 trials are listed in columns 2 and 3. Each subject in a given row had an identical set of reservation values during the experiment. Comparison between observed individual subject earnings to predicted bilateral truthful revelation highlights considerable individual differences. The bottom two rows of the table report the

average percentage of earnings achieved by both buyers and sellers compared to what was achievable under bilateral truthful bidding. Across conditions, buyers successfully claimed

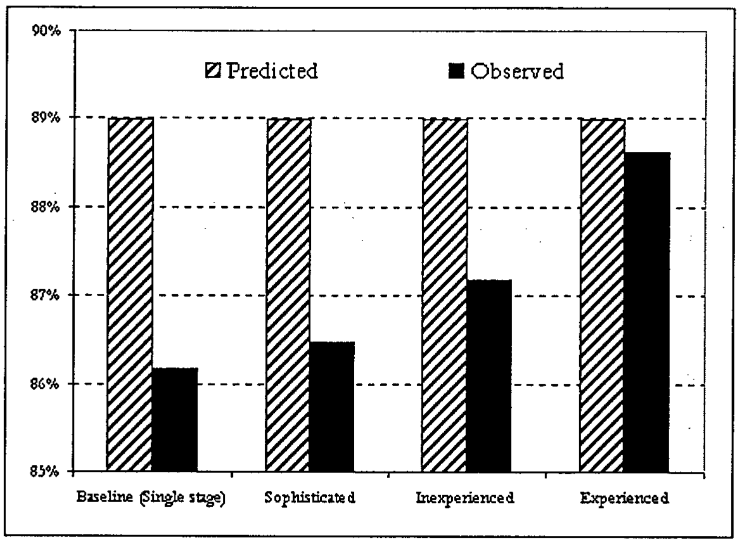
TABLE 4-9. Two-stage Earnings Summary

	Truth (25 trials)	Truth (50 trials)	Baseline		Inexperienced		Sophisticated	Experienced	
Buyers	594	1439	1803	1474	1386	1853	562	1734	1860
	863	1390	1578	1444	1164	1437	1023	1390	1258
	667	1417	1395	1105	1716	1364	714	1661	1698
	790	1458	1628	1195	1259	851	967	1710	1826
	806	1424	1552	1521	1528	1371	1079	795	1557
	507	1517	1638	1388	988	1847	573	1625	1834
	739	1481	1400	1227	1619	1293	827	1504	1648
	791	1570	1452	1470	1477	1862	939	1967	1760
	697	1533	1647	1669	1398	1553	833	1909	1642
	995	1495	1743	1738	1638	1890	1059	1588	1671
Sellers	500	1259	960	838	1352	814	394	1143	321
	862	1727	1139	1117	1255	1459	514	1161	1383
	692	1365	930	978	969	1077	491	529	1007
	849	1540	1014	1207	1108	1402	515	771	1130
	870	1600	1039	1237	888	1162	411	1207	981
	787	1490	919	1083	1239	972	476	1313	887
	923	1537	991	913	1407	1049	551	1162	811
	634	1249	906	997	951	918	384	1186	965
	710	1367	1041	1080	569	955	527	1166	582
	612	1580	1089	1197	1041	1101	423	1094	755
Total	14895	58876	50742		51182		13262	52191	
Mean buyer efficiency			102.2%		100.1%		114.6%	110.6%	
Mean seller efficiency			70.5%		73.8%		64.1%	66.5%	

more than that which would have been available under an equal split if the entire surplus was achieved. Buyers' percentages ranged from 100.1% in the Inexperienced condition to 114.6% with the Sophisticated players. The additional share of earnings claimed by buyers was exclusively at sellers' expense. Sellers consequently performed equally poorly with achieved surplus percentages ranging from 64.1% to 73.8%.

Although none of the differences was statistically significant at α=0.05, the trend toward efficiency steadily increased with the addition of a second stage to the game. Figure 4-11 reports observed efficiency of the two-stage treatments compared to both the single-stage game and the predicted earnings under the single-stage equilibrium. As the level of sophistication decreased and experience with the mechanism increased, the unrealized surplus fell by 3.4% from 13.8% to 11.4%.

FIGURE 4-11. Predicted versus Observed Bargaining Efficiency



(4) Two-stage Discussion. The addition of a second stage to the traditional single-stage mechanism has an efficiency improving effect. However it is the sophistication and experience of the subjects that seem to determine its magnitude. Theoretical predictions relegate the two-stage mechanism as proposed to the single-stage mechanism since players should not reveal any information in stage 1 bidding and thus, consummating no deals. However, stage 1 deals were observed in all treatments. Because of the asymmetric common

priors in all three treatments, buyers had much more to lose by making truthful stage 1 offers. Sophisticated buyers and sellers alike quickly learned that any information revealing offers during stage 1 was a dominated strategy. Inexperienced buyers exhibited a similar response, however the Inexperienced sellers did not. With increasing experience, Inexperienced buyers became more aggressive with stage 1 offers despite the fact that, on average, they never bid more than b_1<50. The Inexperienced sellers, on the other hand, made information revealing stage 1 offers throughout the experiment with very little change over time. Perhaps because the Inexperienced sellers demonstrated poor adaptive behavior during stage 1 play as an aggregate, the buyers continued making deals with very low stage 1 bids and subsequently lowered their offers in hope of greater earnings. The Experienced players, having been indoctrinated through class discussions on bargaining specifically focused on their previous results during a single-stage game, jointly demonstrated some cooperative behavior during stage 1 play—both buyers and seller making information revealing stage 1 offers. However, this cooperative behavior eroded midway through the experiment with both types simultaneously crossing their respective information revealing thresholds. Consequently, the Experienced players enjoyed greater overall earnings as a result of bilaterally deviating from stage 1 equilibrium predictions. All players in all treatments exhibited strategic stage 1 offers. However, because the Experienced players demonstrated this behavior far less than the Inexperienced of Sophisticated groups, not only did they achieve nearly twice the number of deals during stage 1, but also came to agreement on bargains more frequently during stage 2 because of information gained from stage 1. Although the absolute magnitude in efficiency improvement is small, adding a second stage

appears to have a discernable effect because it capitalizes on the players' inexperience and/or depth of reasoning. However, with sufficient experience, this effect diminishes and eventually disappears altogether.

Stage 2 results cannot be compared directly with the single-stage mechanism results given that players made deals during stage 1. However, without accounting for this difference, the overall effect on earnings is not significant. Interestingly enough, the two-stage mechanism results provide further evidence of the RDS Information Disparity Hypothesis that information advantaged players will use their advantage in a manner that will force the co-bargainer to concede more than predicted by the LES. Across treatments, buyers collectively claimed at least as much of the surplus that they could have otherwise claimed by truthfully bidding and achieving efficiency, all at the expense of the sellers. Inexperienced sellers performed better than sellers in the single-stage game primarily because the Inexperienced buyers were less aggressive than the Baseline buyers. However, both the Experienced and Sophisticated buyers were considerably more effective in controlling their respective sellers' offers earning a 10-15% premium above a fair division efficient surplus split at a 35% efficiency loss to the sellers. Regression analysis of the stage 2 offers indicated negligible differences between single-stage and two-stage mechanisms. Differences between the mechanisms seem to be attributable to the conditioning effects of stage 1 offers. For instance, because Experienced sellers were relatively less aggressive than Experienced buyers during stage 1, the spline function for the Experienced buyers' stage 2 bids depicts more pronounced aggressiveness than the Baseline buyers and less aggressiveness for Experienced sellers, particularly at the highest reservation values. As with many of the other observed

patterns, this trend appears more prominently over time with increasing experience not only with the mechanism, but also with the particular samples of players in the experiment. Chapter VI takes this analysis one step further by analyzing the dynamic trends in behavior through investigation of a reinforcement-based adaptive learning model.

CHAPTER V: VARYING-*k* MECHANISM

A. INTRODUCTION

An interesting but largely unexplored question pertaining to the sealed-bid *k*-double auction institution involves varying the trading parameter, *k*. Because extreme values of *k* are more prominent in application where one of the bargaining party's offers dictates the trading price given that a deal is made, understanding the impact of varying *k* in light of all that is already known about bilateral bargaining is an important step in developing models of human bargaining behavior. The focus of this chapter is the evaluation of extreme values of *k* when one player has a distinct information advantage.

(1) Overview of the Varying-*k* Study. The experimental design for this study differs in several important ways from studies reported in Chapters III and IV. Not only does *k* take on extreme values, but the common priors, F~uniform[α_s, β_s] and G~uniform[α_b,β_b] also are modified. Unlike Chapters III and IV where $\alpha_s=\alpha_b=0$ and $\beta_b/\beta_s=2$, the relative difference between the ranges in the present study has been increased by a factor of ten. Both DSR and SDR used similar supports and found consistent support for the LES noting that the information-advantaged player garnered a larger portion of the surplus than predicted. By increasing the information disparity between buyer and seller, the information-advantaged party has little uncertainty regarding his co-bargainer's valuation. By allocating a distinct information-advantage and price setting power to each type of player, the reported experiments aim to identify the effects and interrelationships on equilibrium behavior.

(2) Experimental Design. Table 5-1 outlines the 2x2 design for the varying-k experiments. Two letters identify each condition: 'B' denoting the buyer and 'S' the seller. The first letter identifies which player has the information advantage and the second, the player who unilaterally determines the trade price. In Condition BB, the buyer is afforded the information advantage by constraining the seller's upper limit, β_s=20, and retaining the same values for α_s, α_b, and β_b, as in previous chapters. The buyer is also afforded unilateral power to set the trade price (k=1) with his bid, provided an agreement is reached ($p=b \mid b \geq s$). Condition SS is isomorphic to Condition BB with the only difference being that all power is, instead, given to the seller. By setting α_b=180, α_s=0 and β_b= β_s=200 with k=0, the seller unilaterally determines the trade price if the parties achieve a deal ($p=s \mid b \geq s$) with the seller having little certainty as to the buyer's reservation value. Together,

TABLE 5-1. Experimental Design, Varying-k

	Buyer sets trade price	Seller sets trade price
Buyer Information Advantage	Condition BB F~[0,20], G~[0,200] k=1	Condition BS F~[0,20], G~[0,200] k=0
Seller Information Advantage	Condition SB F~[0,200], G~[180,200] k=1	Condition SS F~[0,200], G~[180,200] k=0

(1) Conditions BB and SS → Dominating Player Treatment
(2) Conditions BS and SB → Balanced Power Treatment

these two conditions comprise the Dominating Player Treatment, where one player has both an information advantage and price setting power. On the other hand, Condition BS yields

the information advantage to the buyer but gives price setting power to the seller. Similarly, Condition SB does just the opposite: the seller has the information advantage and the buyer gets to set the price. Collectively, these two conditions make up the Balanced Power Treatment where one player has the information advantage whereas the other player gets to determine the trade price by his or her offer, given that an agreement is reached. The primary question of interest for this study is to what extent an information advantage is mitigated by price setting power and vice versa. However, because the experimental design pushes both the information advantage (disadvantage) and trade price determination to the outer boundaries, other questions of importance also include how observed behavior compares to the LES and to what extent behavior compares to previous studies in these extreme conditions.

Relying on RDS's previous findings of no differences between buyers and sellers in identical parameterizations of games interchanging only buyer and seller roles, each cell only contains one group. For purposes of replication within condition, Condition BB and SS are considered together as replications of the Dominating Player Treatment while Conditions BS and SB are considered jointly as replications of the Balanced Power Treatment.

B. Theory

Under the k-double auction bargaining mechanism, simultaneously the seller submits an offer $s=S(v_s)$ and the buyer submits a bid $b=B(v_b)$. Trade occurs at price $p=kb+(1-k)s$, if and only $b\geq s$. Previous experimental work on this mechanism has traditionally employed a "midpoint rule" setting the trading parameter to $k=½$ and yielding a price halfway between

the buyer's bid and seller's ask. If, $k=0$, then it is the seller who sets the price unilaterally and the buyer's offer is only relevant to determine whether a deal is reached, $b \geq s$. Provided an agreement is reached, they buyer's bid, b, has no influence on the trade price and subsequent earnings. Conversely, if $k=1$, the buyer sets the price unilaterally and the seller's ask, s, is only necessary in determining whether or not the players are in agreement. Chatterjee and Samuelson proved that values of k where $0 \leq k \leq 1$, $k \neq ½$ yield more "power" to one of the bargainers when the seller's and buyer's commonly known priors are distributed identically and symmetrically.[47] Although CS's theoretical analysis only addressed symmetric common priors, subsequent analysis has extended their findings to any pair of overlapping uniform distributions (Stein and Parco, 2001) regardless of symmetry.

Equations (5.1) – (5.4) present the LES for conditions in the Dominating Player Treatment. Note the similarity of equations (5.1) and (5.4) as well as (5.2) and (5.3). A similar relationship is evident in equations (5.5) – (5.8) for the Balanced Power Treatment. Equations (5.5) and (5.8) are effectively identical as are equations (5.6) and (5.7) relating Conditions BS and SB. The only difference between any related pair of equations is the inversion of F and G (prior probability distribution of the seller and buyer, respectively) to place buyers and sellers in otherwise identical information positions. Figure 5-1 plots the LES solutions for each pair of equations for the four conditions investigated in this chapter.

[47] "Power" is inferred to mean the ability for a player in increase his proportion of the surplus (1983).

<u>DOMINATING PLAYER TREATMENT: Condition BB LES (F~U[0,20], G~U[0,200], k=1)</u>

$$b = B^*(v_b) = \begin{cases} \frac{1}{2} v_b & v_b \le 40 \\ 20 & 40 < v_b \le 200 \end{cases} \tag{5.1}$$

$$s = S^*(v_s) = v_s \qquad \forall \ v_s \tag{5.2}$$

<u>DOMINATING PLAYER TREATMENT: Condition SS LES (F~U[0,200], G~U[180,200], k=0</u>

$$b = B^*(v_b) = v_b \qquad \forall \ v_b \tag{5.3}$$

$$s = S^*(v_s) = \begin{cases} 180 & v_s \le 160 \\ \frac{1}{2} v_s & 160 \le v_s \le 200 \end{cases} \tag{5.4}$$

<u>BALANCED POWER TREATMENT: Condition BS LES (F~U[0,20], G~U[0,200], k=0</u>

$$b = B^*(v_b) = \begin{cases} v_b & v_b \le 110 \\ 110 & 110 < v_b \le 200 \end{cases} \tag{5.5}$$

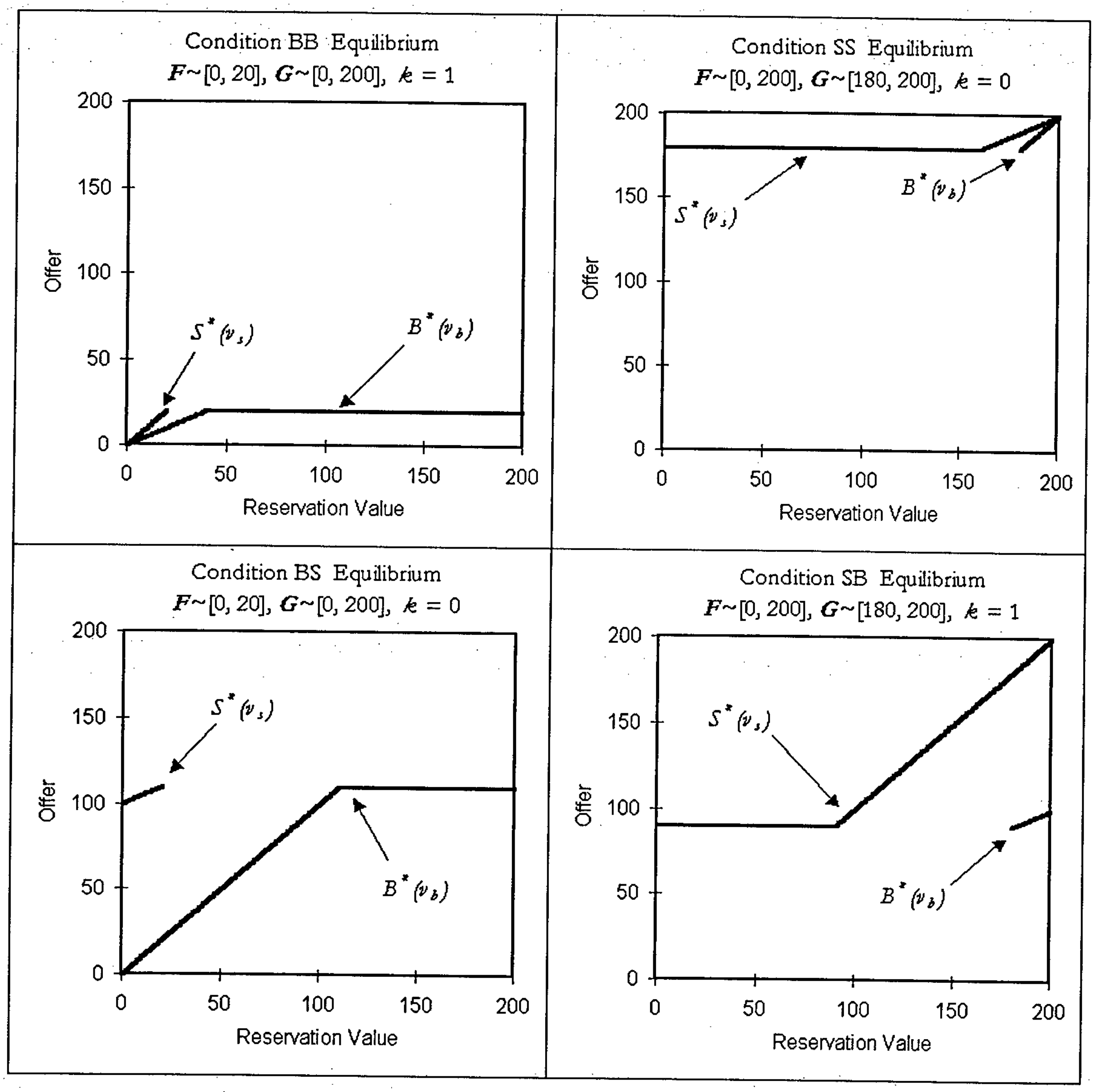
$$s = S^*(v_s) = 100 + \frac{1}{2} v_s \qquad \forall \ v_s \tag{5.6}$$

<u>BALANCED POWER TREATMENT: Condition SB LES (F~U[0,200], G~U[180,200], k=1</u>

$$b = B^*(v_b) = 90 + \frac{1}{2} v_b \qquad \forall \ v_b \tag{5.7}$$

$$s = S^*(v_s) = \begin{cases} 90 & v_s \le 90 \\ v_s & 90 < v_s \le 200 \end{cases} \tag{5.8}$$

FIGURE 5-1. Linear Equilibrium Strategies for Varying-*k* Conditions



The vast majority of experimental research has relied on experimental designs that exclusively set the trading parameter to $k=½$ (e.g., Radner and Schotter, 1991, Daniel et. al, 1998, Rapoport et. al, 1999, Seale et. al, 2001) despite the fact that many applications of the sealed-bid mechanism often employ an extreme value of *k* where one of the bargaining parties determines the trade price by being the highest (or lowest) offeror. Theoretical

analysis suggests that the expected profit of a seller (buyer) is decreasing (increasing) in k (CS, 1983). However, the literature is silent on *ex post* efficiency for values of $k \neq ½$.

The principal aim of this study is to explore the effect of k on the efficiency of bargaining and the strategies employed by the buyers and sellers. For example, under equilibrium play if k=0, the buyer should be "truth telling" always bidding his reservation value, whereas the seller should behave strategically and place asks that exceed her reservation value. A second and related goal is to determine whether the information advantage (which is a function of the commonly known distribution of reservation values that differ one from the other) found in previous studies holds when one bargainer is conferred with increased price setting power by varying k.

C. METHOD

(1) Subjects. Sixty undergraduate students from the University of Arizona and twenty economics graduate students[48] participated in four separate sessions with payment contingent on performance. Undergraduate participants in Conditions BB and BS were recruited in the standard way (as described in Chapter I) and paid $5.00 for arriving on time. The undergraduate participants in Condition SS were a subset of students enrolled in a bargaining class and were given the opportunity during class time to participate with the added incentive that their performance also counted toward their final course grade. These students were midway through the course and had participated in both a single-stage and

[48] These "sophisticated" players were different subjects from those who participated in the two-stage study of Chapter IV.

two-stage bargaining experiment previously as well as had discussed both experimental results and theoretical solutions for a single-stage game with $k = 1/2$. The graduate student group (Condition SB) was comprised of participants from a summer workshop sponsored by the International Foundation for Research in Experimental Economics and the Economics Science Lab (ESL). Like the sophisticated group reported on in Chapter IV, these students also had extensive training in graduate-level microeconomics.

Verbal communication with one another was strictly prohibited and all subjects were guaranteed anonymity. Each session lasted approximately sixty minutes. Participants in Conditions BB, SS and BS (undergraduate groups) earned $1.00 US for every 100 francs with payments ranging from $4.90 to $31.98. Participants in Condition SB (graduate students) earned $1.00 US for every 50 francs with payments ranging from $24.94 to $45.76.

(2) Procedure. Participants randomly drew seat assignments in the ESL by individually selecting a chip from a bag containing twenty chips labeled with the cubicle numbers of the stations in the lab. Each subject was individually seated and given a set of written instructions to read at his or her own pace. Once all subjects completed reading the instructions (see Appendices G through J) the experiment began. The same procedure was used for all four conditions reported in this study.

Each subject participated in fifty trials of a single-stage bargaining game. The subjects were explicitly instructed that their bargaining partners were randomly varied from trial to trial. At the beginning of each trial, players privately received a reservation value randomly drawn with equal probability from their respective distributions. The computer required subjects to privately and independently submit their offers and confirm the

responses. If an offer could result in a loss (i.e., if $b>v_b$ or $s<v_s$), a message was displayed to the specific player prior to confirmation. After all twenty subjects responded, everyone was informed (each pair separately) whether a deal was struck and, if so, the calculated the payoff for each. Subjects were also informed of their decision, their co-bargainer's decision, and the trade price. Each player was also privately informed of his or her earnings for the trial.

D. RESULTS

(1) Within Treatment Comparisons. Because conditions within each treatment are isomorphically identically structured, tests for differences are possible by comparing buyers of one condition with the sellers of the other condition within each treatment. Because each subject had a different set of randomly drawn reservation values which were not identical between conditions within each treatment, the mean absolute percentage error or "MAPE" (a standard measure of difference) has been adopted to make appropriate comparisons. For each decision, the percentage error was calculated by finding the difference between the offer and the prescribed LES offer and dividing it by the LES offer. The mean MAPE was then computed

TABLE 5-2. Mean Absolute Percentage Error between Offers and LES

	Dominating Player		Balanced Power	
	BB	SS	BS	SB
Mean Buyer MAPE	1.671	0.102	0.195	0.382
Mean Seller MAPE	3.557	0.075	0.283	0.186

for each subject. The mean MAPE by role in each condition is reported in Table 5-2. The difference between buyers and sellers in the Balanced Power Treatment was small (compare diagonals), while the difference in the Dominating Player Treatment was notably larger. Using a

standard t-test, there were no significant differences within the Balanced Power Treatment between mean MAPE of information-advantaged and information-disadvantaged players. Neither the comparison between BS Sellers and SB Buyers (p=0.323) nor the comparison between SB Sellers and BS buyers (p=0.613) yielded significant differences. However, there were differences between Conditions BB and SS in the Dominating Player Treatment. Both comparisons between the buyers and sellers of each condition were significant at p=0.002. The reasons for this difference are unclear. An unlikely but plausible hypothesis is that there exists a difference between buyers and sellers despite previous work by RDS showing otherwise. A second and more likely hypothesis is that experienced subjects (used in Condition SS) behaved differently than the typical inexperienced subjects.[49] Additional data is necessary before generalizing findings within the Dominating Player Treatment as the treatments are confounded with differing levels of experience/sophistication within subject populations.

(2) Individual Data.

(a) Dominating Player Treatment.

(i) Condition BB, Buyers. With the exception of BB Buyer 4, all of the buyers bid less aggressively than predicted by the LES (Figure 5-2a). BB Buyer 4 is an exception who consistently bid between $21 \leq b \leq 31$ for all $v_i > 20$ across trials earning 3198 francs, the most of any subject in the experiment. BB Buyer 10 is another exception who bid b=100 on Trial 1 and then consistently bid b=20, b=30 or b=40 (two cases of b=45 and b=50) bidding b=50 twice as well as b=45 twice. At the other extreme, BB Buyer 2 made relatively truthful bids with

[49] Evidence of experienced players reported in Chapter IV substantiates this.

FIGURE 5-2a. Condition BB, Buyers, F~[0,20], G~[0,200], k=1

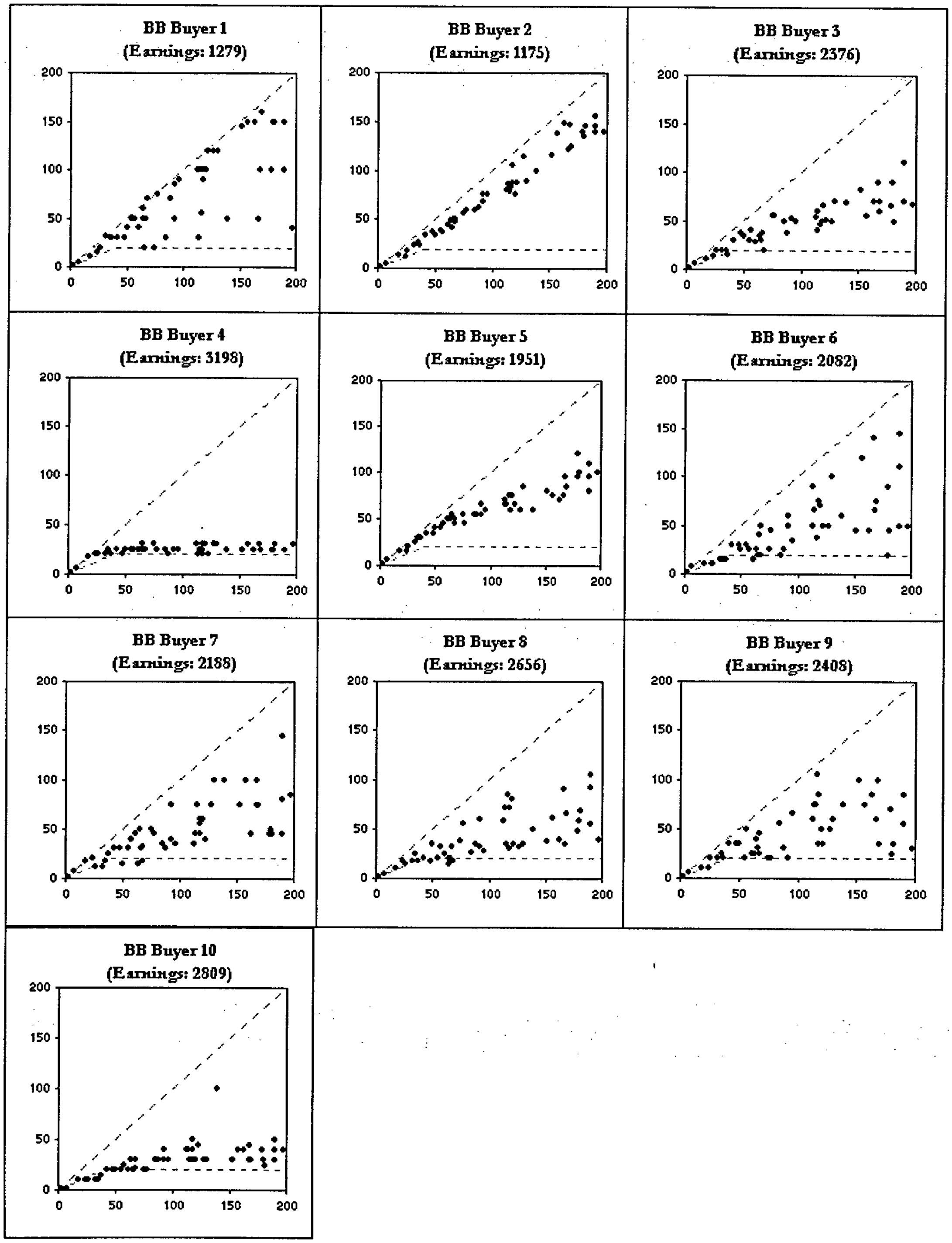
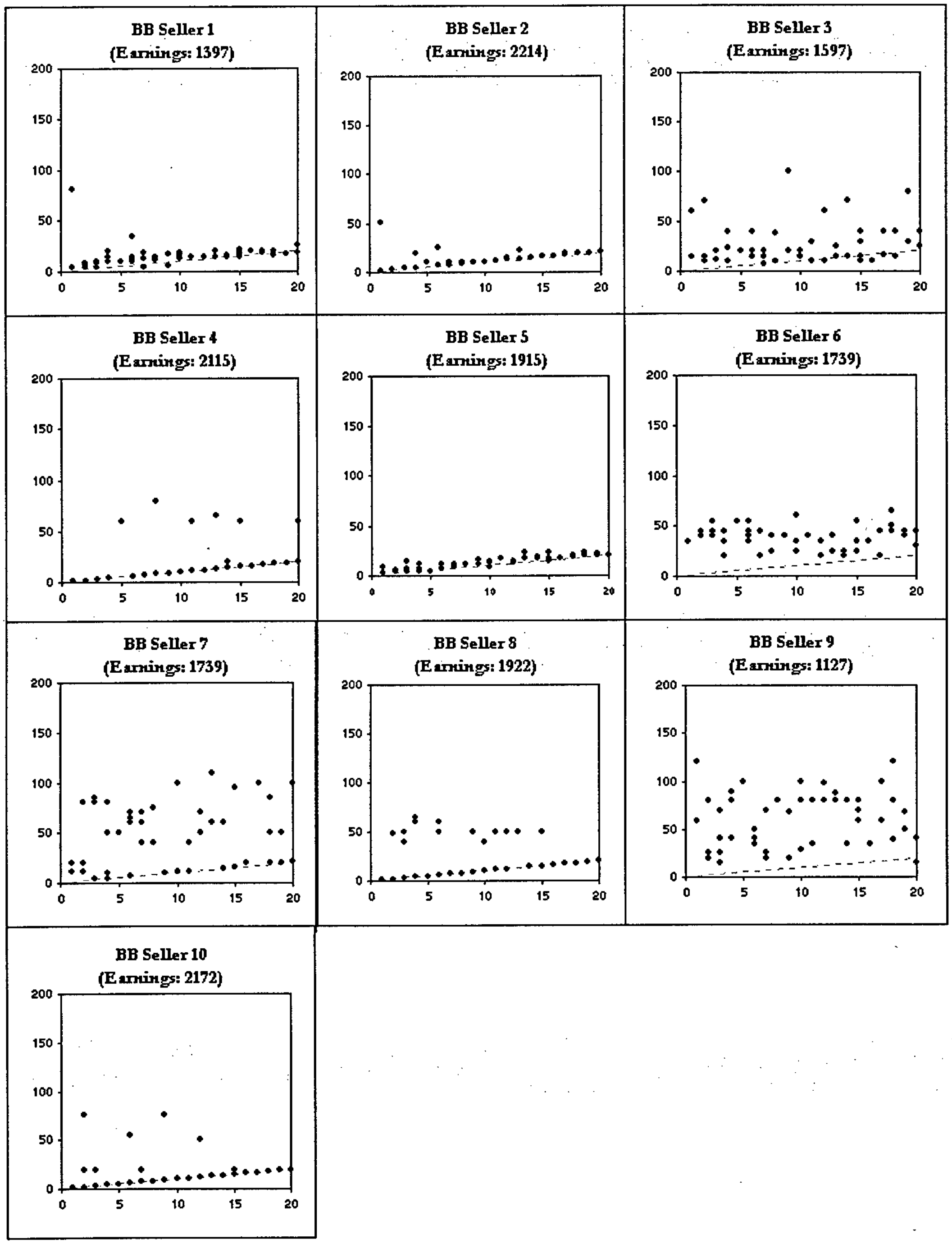


FIGURE 5-2b. Condition BB, Sellers, F~[0,20], G~[0,200], k=1



increasing (although minor) shaving for increasing v_b. BB Buyer 2 achieved 44 deals (the most) and earned 1175 francs (the least). The other buyers in the condition varied to differing degrees between the LES and truth telling functions. Only one subject (BS Buyer 1) made a single losing offer bidding b=70 with a reservation value of v_b=68 during Trial 5 but then made no further mistakes.

(ii) Condition BB, Sellers. Mistakes for the BB sellers were not as costly since the buyers' offers determined the trade price. BB Sellers made fifteen losing offers with thirteen of them resulting in deals, all of which were profitable. Sixty percent of the sellers (BB Sellers 1, 2, 4, 5, 8 and 10) made offers in close approximation to the LES, which corresponded with truth telling. The other four subjects made far more aggressive offers resulting in fewer deals and subsequently fewer earnings. BB Seller 4 provides an interesting example. She made six offers in excess of s>50 intermittently between Trials 21 and 41, almost as to signal to the buyers not to get too aggressive. BB Seller 8, on the other hand, made offers of $s \geq 50$ or more during the first fifteen trials, but suddenly reverted to truth telling behavior for the remainder of the experiment. The other sellers (BB Sellers 3, 6, 7 and 9) made very aggressive offers, at times bidding more than b>100, refusing to be "pushed down" by the information-advantaged buyers.

(iii) Condition SS, Buyers. SS Buyer 2 made two losing offers on Trials 49 and 50 both resulting in profitable deals (Figure 5-3b). Two buyers (SS Buyers 9 and 10) followed the LES prescribed truth-telling strategy. SS Buyer 9 only made two strategic offers on Trials 1 and 2. The remaining SS Buyers exhibited a variety of strategic offers, mostly in the range $150 \leq b \leq 180$. Only 6.2% (31/500) of total bids were below b<150 and less than a half of 1% fell

FIGURE 5-3a. Condition SS, Buyers, F~[0,200], G~[180,200], k=0

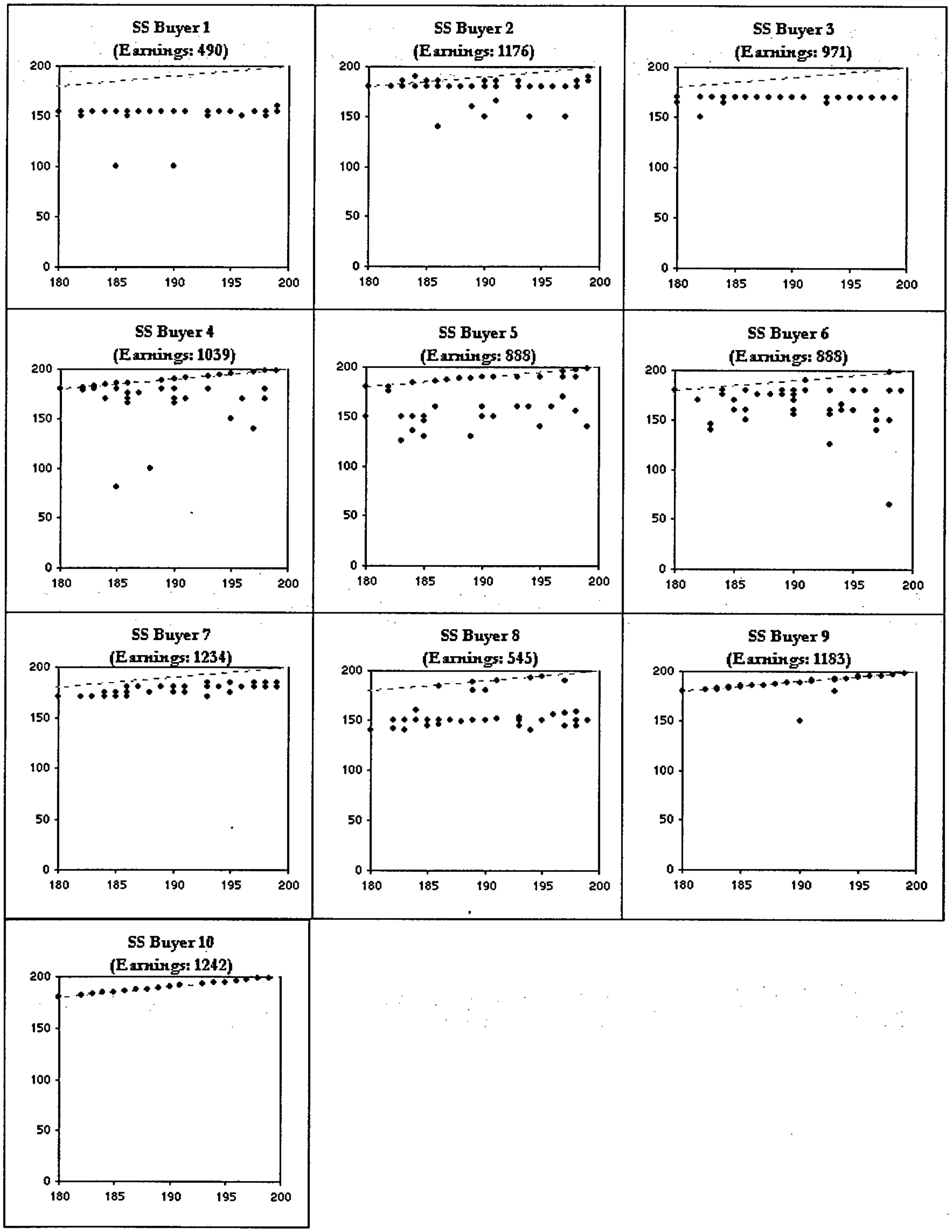
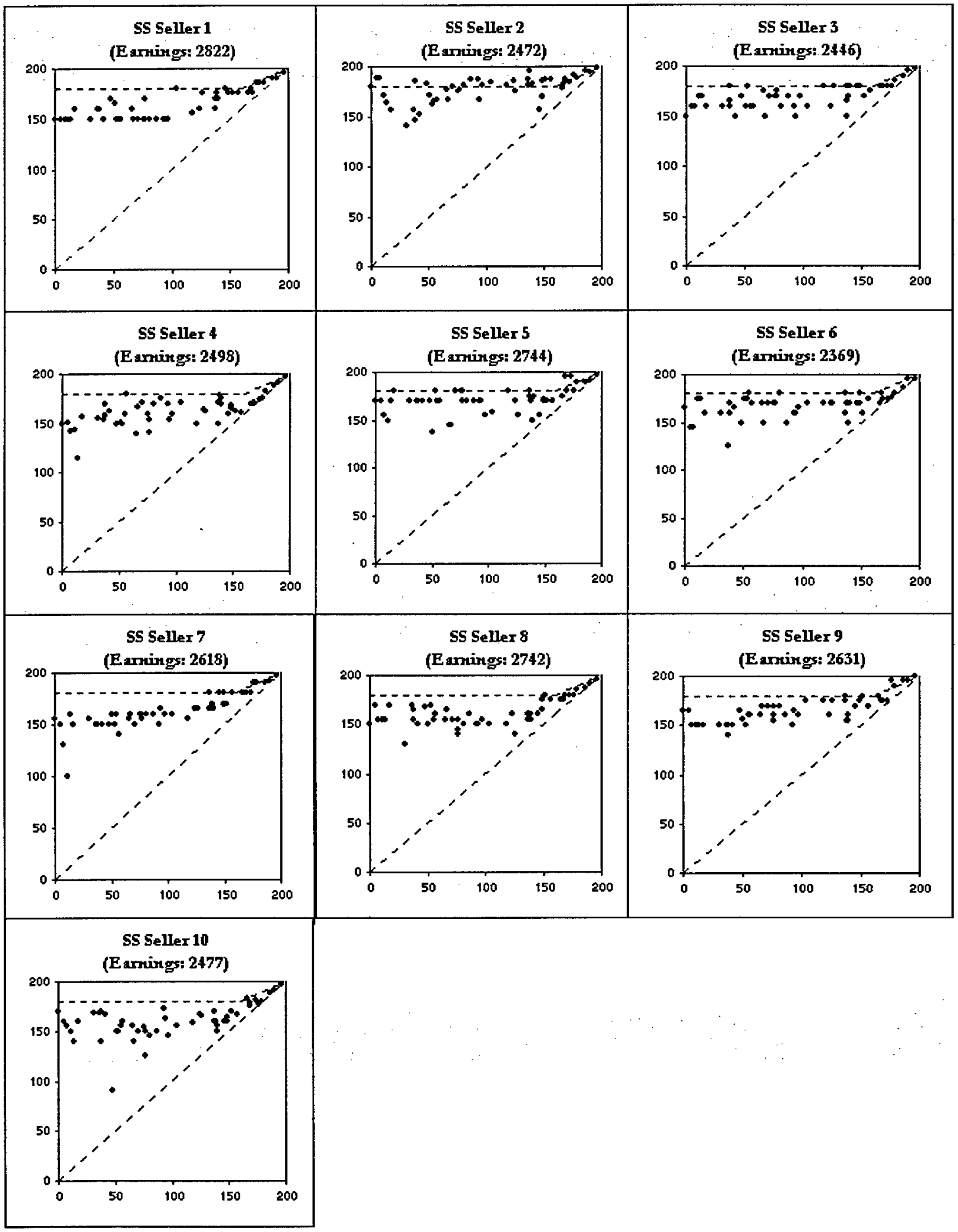


FIGURE 5-3b. Condition SS, Sellers, F~[0,200], G~[180,200], k=0



below b<100. SS Buyers 1 and 8 demonstrated the most aggressive behavior and subsequently earned the least (490 francs and 545 francs, respectively).

(iv) Condition SS, Sellers. SS Sellers' behavior was relatively homogeneous with SS Seller 2 being the only one that made a considerable number of offers which were more aggressive than predicted by the LES. The rest of the SS Sellers were less aggressive with the preponderance of offers falling in the range $150 \leq s \leq 180$, similar to that of the SS Buyers. Only one instance of an ask s<100 occurred with SS Seller 10 during Trial 6 as well as a single ask by SS Seller 7 on the first trial of s=100. Overall, only 5.8% of asks were below s<150.

(b) Balanced Power Treatment.

(i) Condition BS, Buyers. The information-advantaged BS Buyers exhibited remarkable adherence to the LES predictions of truthful revelation for $0 \leq v_b \leq 110$ (Figure 5-4a). However, none of the BS Buyers' strategies leveled off as predicted. BS Buyer 4 was the only player that bid more aggressively than predicted--consistent with evidence of information-advantaged players in previous studies. Six out of ten subjects (BS Buyers 3, 5, 6, 7, 8, and 9) bid truthfully without any (or with only very negligible) shaving. BS Buyers 1, 2, and 10 fell between the LES and truth-telling for the highest reservation values tending toward the dominated truth-telling strategy in most cases.

(ii) Condition BS, Sellers. Like the buyers, observed behavior for sellers in Condition BS was relatively stable and consistent across players (Figure 5-4b). Three subjects (BS Sellers 3, 5, and 8) made offers somewhat around the LES, but $^{7}/_{10}$ sellers were much less aggressive than predicted by the LES. No learning was evident for any of the players.

FIGURE 5-4a. Condition BS, Buyers, F~[0,20], G~[0,200], k=0

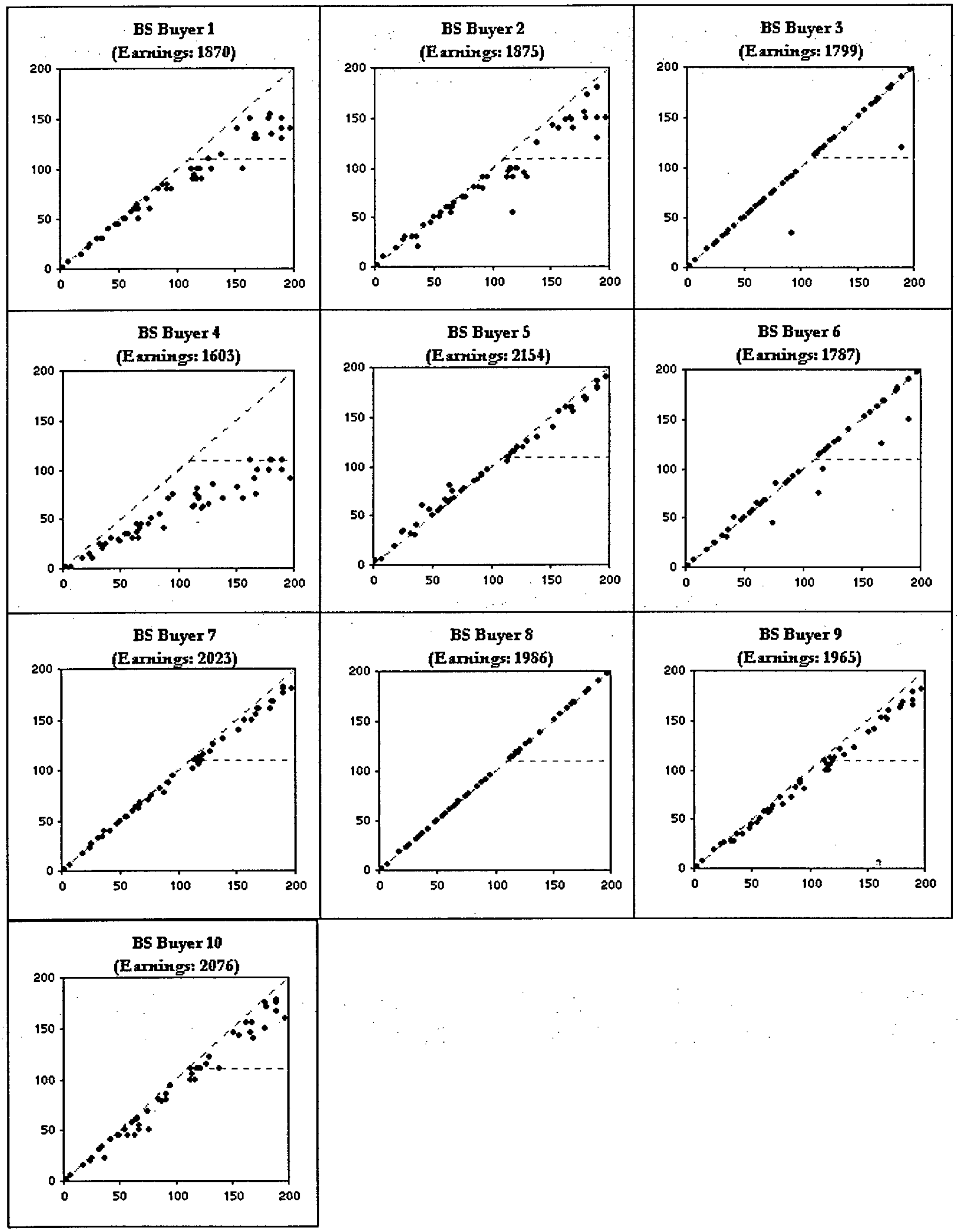


FIGURE 5-4b. Condition BS, Sellers, F~[0,20], G~[0,200], k=0

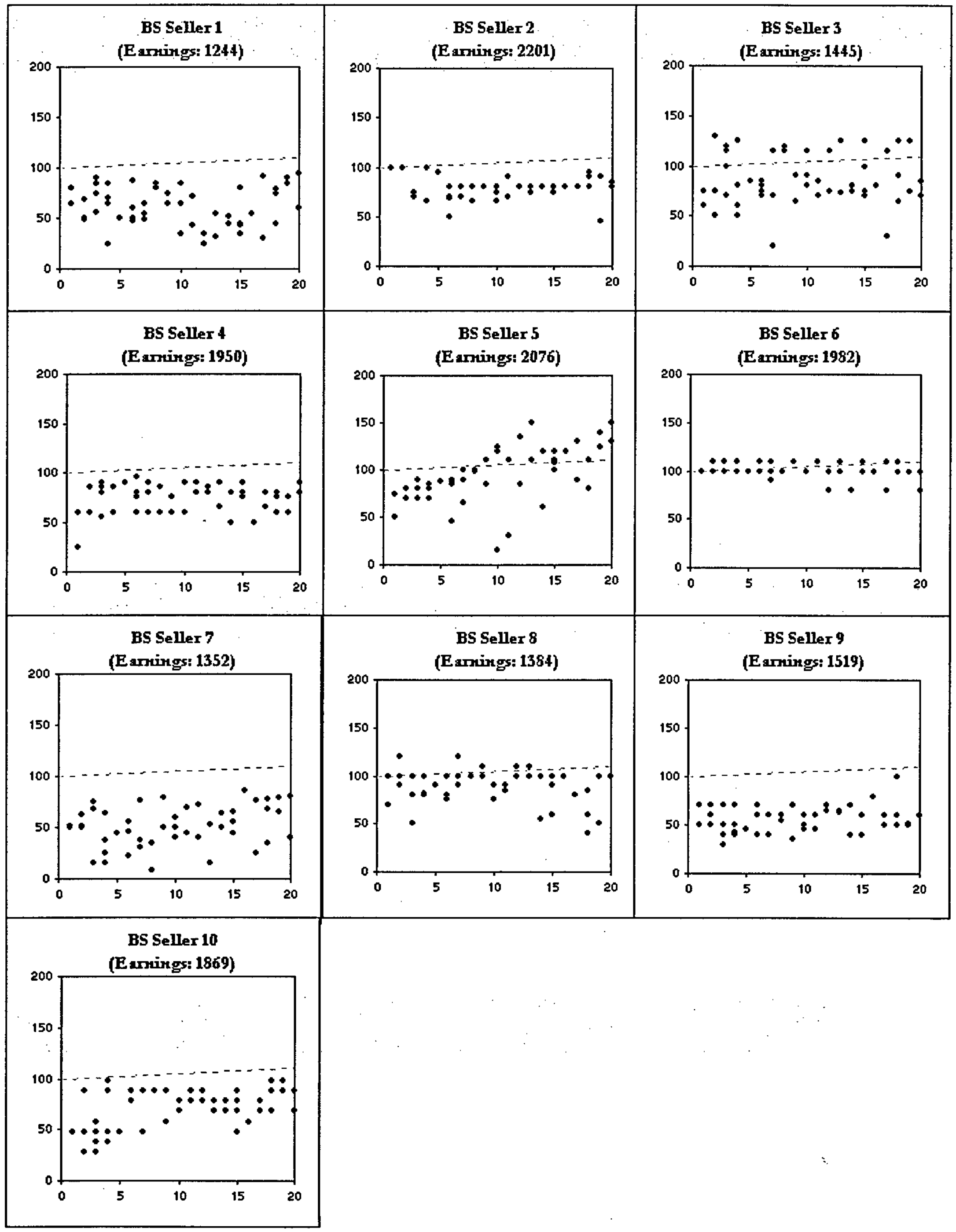


FIGURE 5-5a. Condition SB, Buyers, $F \sim [0,200]$, $G \sim [180,200]$, $k=1$

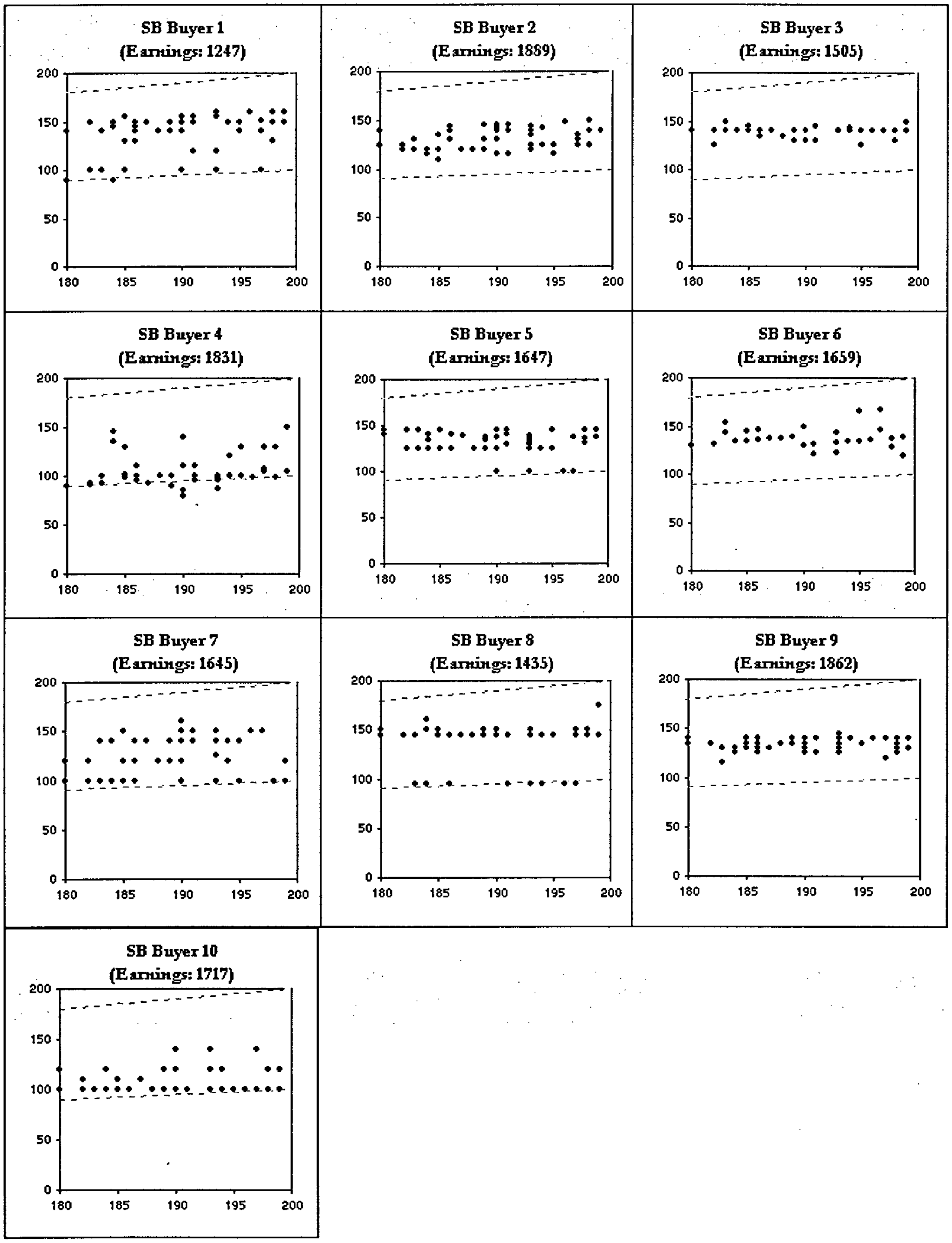
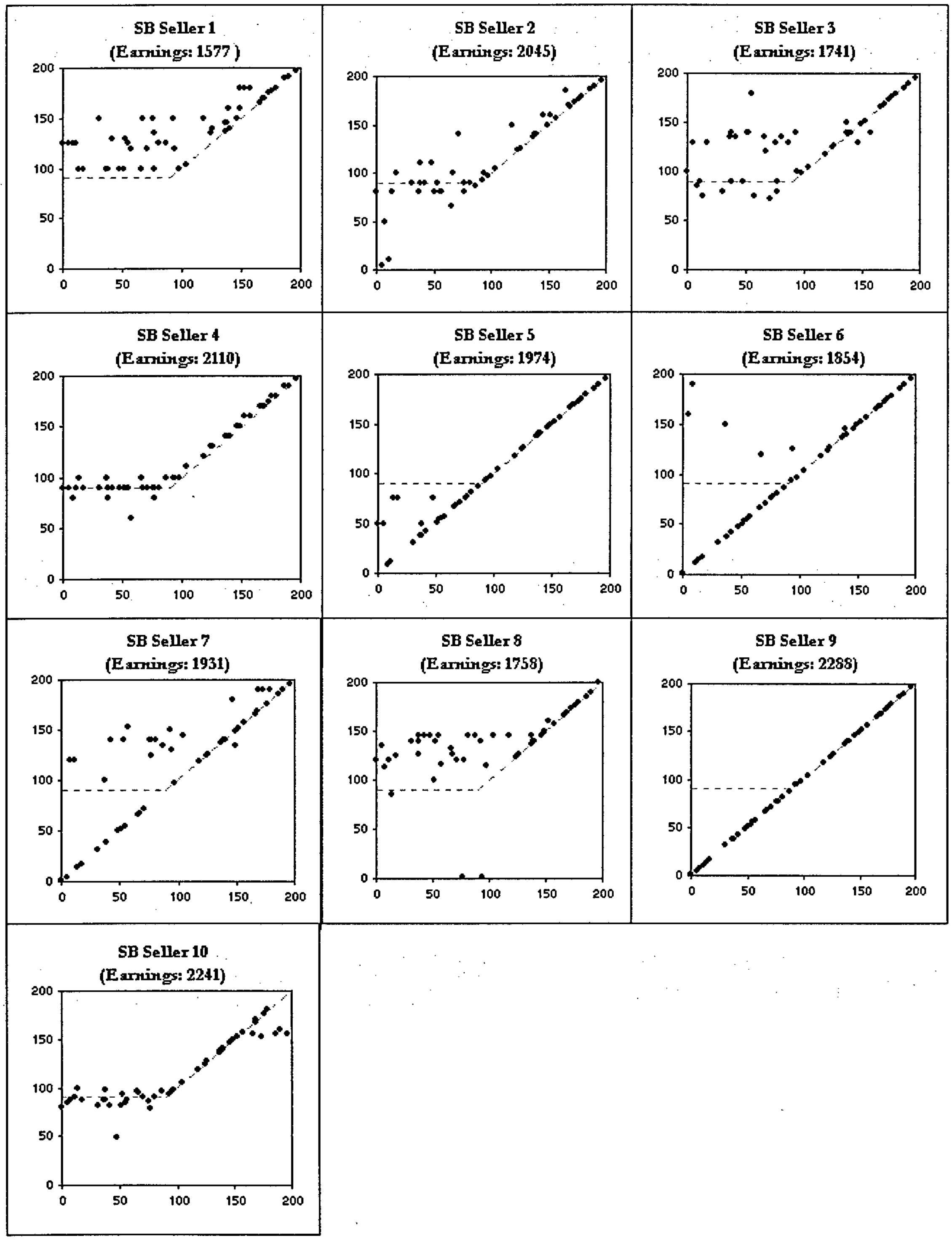


FIGURE 5-5b. Condition SB, Sellers, F~[0,200], G~[180,200], k=1



(iii) Condition SB, Buyers. Buyers in Condition SB were information-disadvantaged but had price setting power--directly comparable to the isomorphically identical sellers in Condition BS. Not surprisingly, data from SB Buyers look remarkably similar to that of the BS Sellers (Figures 5-5a). Only one player (SB Buyer 4) made any bids that were more aggressive than predicted and only four of them in total. All SB Buyers were far less aggressive than predicted, although there were no occurrences of truth-telling behavior given that doing so would result in zero profits with certainty. Observed behavior was homogeneous across subjects and equally varied across trials yielding no indications of learning.

(iv) Condition SB, Sellers. The information-advantaged sellers of Condition SB are isomorphically identical to the buyers of Condition BS although behavior observed in SB Sellers is closer to LES predictions (Figures 5-5b). SB Sellers 1, 3 and 8 made more aggressive offers than predicted. SB Sellers 5, 6 and 9 were less aggressive following truthful revelation strategies. SB Sellers 2, 4, and 10 followed LES prescriptions almost exactly. The most interesting subject in the condition was SB Seller 7. For reservation values v_s>90, SB Seller 7 adhered to the LES truth telling prescription. However, for v_s<90, observed behavior lies at the extremes: half of the offers are truthful where as half are far more aggressive than equilibrium behavior. During the first 19 trials, SB Seller 7 made considerably strategic offers for v_s<90. However, because many of the offers did not result in deals, he made truthful offers on all remaining trials with a single exception during Trial 24.

(3) Aggregate Analysis. Figures 5-6 and 5-7 illustrate the best fitting linear functions using ordinary least squares (OLS) for the four varying-*k* conditions. Because the LES predicts a piece-wise linear function for the information-advantaged player, spine regression was used

fixing the knots[50] regressing v_b on b and v_s on s. Simple linear regression was used for the information-disadvantaged players. An important result across conditions is the reversal of a previously robust finding across experiments under asymmetric information conditions: the information-advantaged player *does <u>not</u> bid (ask)* more aggressively than predicted by the LES.

Conditions BB and BS replicate the information asymmetry[51] of SDR's Condition SLA experiment (F~U[0,200] and G~U[180,200]) with the only difference being the value of k. Whereas in DSR's Condition SLA, k=$^1/_2$, Condition BB of the present study set k=0 and Condition BS set k=1. Unlike Condition SLA where DSR reported consistent behavior with previous studies, namely the information-advantaged player using his or her advantage to extract a larger share of the surplus than predicted by the LES, the varying-k studies yield contradictory effects. In the Dominating Player conditions, conferring price-setting power to the information-advantage player induced *<u>less</u>* aggressive behavior. Not only was the behavior of the powerful player (information-advantaged with price-setting power) less aggressive than that observed in the SDR study, but it was also considerably less aggressive than the LES. Conferring extreme power to a single player seemed to induce a "judo effect" enabling the weak player (information-disadvantaged with only price-veto power) to use the strength of the power player against himself. The information-disadvantaged players, in turn, demonstrated increased aggressiveness preventing the power players to "push them down" as had been noted in DSR, RDS and SDR.

---

[50]"Knots" or "hinge points" refer to the necessary conjunction of the piece-wise linear function at a particular value: v_b=40 in Condition BB; v_s=160 in Condition SS; v_b=110 in Condition BS; and v_s=90 in Condition SB.
[51] Conditions SS and SB implement identical asymmetry in terms of both information and price determination interchanging only player types.

FIGURE 5-6. Dominating Player Treatment Regression Summary

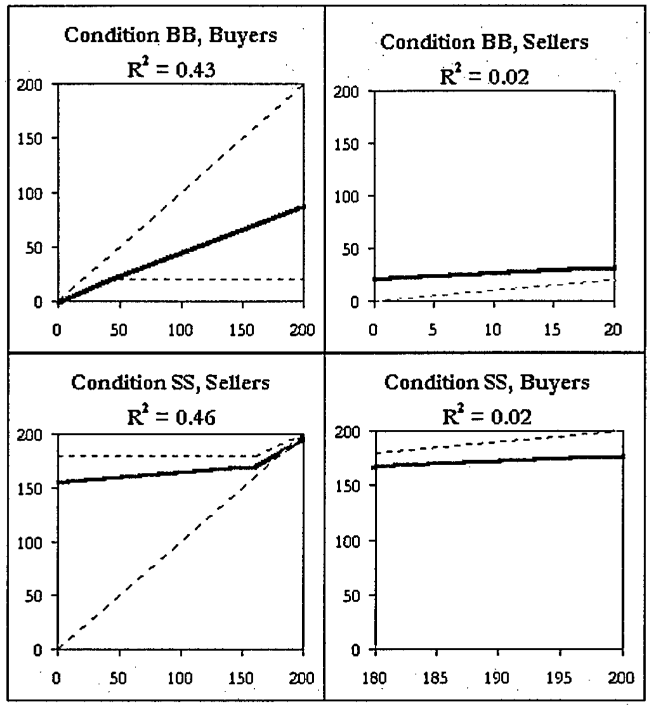


FIGURE 5-7. Balanced Power Treatment Regression Summary

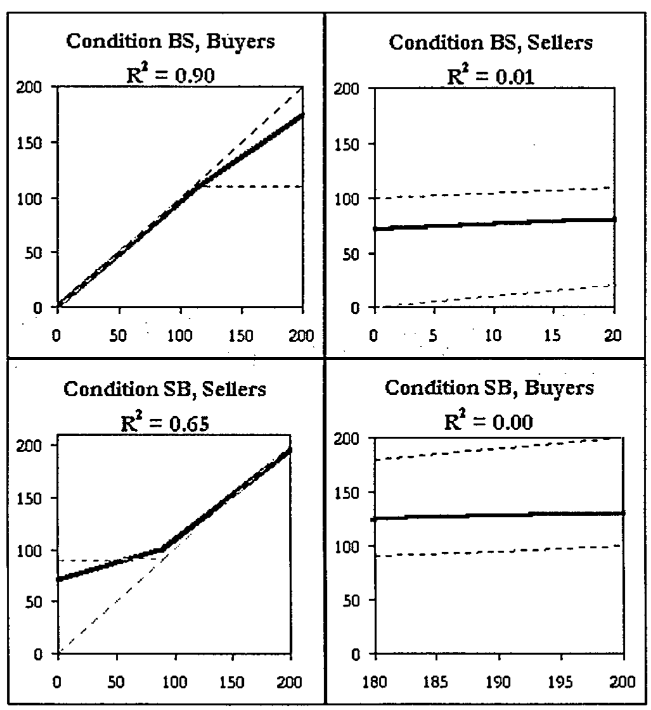


Table 5-3 specifies the spline and linear regression results of Figures 5-6 and 5-7 for all four conditions by block and player role. Across conditions, models for the information-disadvantaged players yielded very poor R^2 values due to the large individual differences over such a small range of reservation values (21 possible values). On the other hand, the coefficient of determination values for information- advantaged players indicated much better fits ranging from R^2=0.42 to R^2=0.90. With the exception of the BB Buyers, the R^2 values increased during the second block of trials indicating convergence to a standard of behavior. In both treatments, information-disadvantaged players behaved more aggressively than predicted with extreme values of k (k=1 and k=0) as opposed to previous studies setting $k={}^1/_2$ ubiquitously. The weak players also performed (1) better than predicted and (2) better than the weak players of the Dominating Player treatment when given price-setting power than in the Balanced Power treatment. An evaluation of the intercepts of the information-disadvantaged players reveals that BB Sellers and SS Buyers deviated from LES prediction by 21.5 and 12.5, respectively, in the Dominating Player treatment. In the Balanced Power treatment, the difference was much more prominent with 29.6 for BS Sellers and 35.8 for SB Buyers.

The LES was poorly supported across conditions and player roles in the Dominating Player treatment except for the upper-most range of reservation values for BB Buyers in Condition BB. BB Buyers bid more truthfully than predicted for reservation values smaller than v_b<40 (observed slope of 0.972 instead of the LES predicted slope of 0.500), although the intercept coefficient was insignificant and assumed to pass through the origin. For reservation values above v_b>40, the LES predicts a slope of zero. Although the regression yielded a slope of 0.385, it is not significantly different from zero and therefore the LES cannot be rejected in this

range. The LES can, however, be rejected for the BB Sellers as both the slope and intercept are highly significant and more aggressive than the LES prediction of truth telling. All coefficients for SS Sellers are significant at $p<0.001$ and far less aggressive than the LES. The SS Buyer model for across trials also exhibits aggressive bidding that differs significantly from the LES.

The LES received inconclusive support in the Balanced Power treatment (relatively weak to moderate support in Condition BS but soundly be rejected in Condition SB).[52] The slope for BS Buyers in the lower range showed minor aggressive behavior, which diminished in the direction of the LES during the course of play from 0.868 to 0.892 (95% confidence interval upper limit--0.925). Because neither the coefficients for the intercept nor the slope for the upper range was significant, the LES cannot be completely discounted for the BS Buyers. The large coefficient of determination values (increasing from $R^2=0.88$ to $R^2=0.92$ over the course of play) indicate that the static model was a good fit and indicative of homogeneity among players. BS Sellers yielded a significant intercept of 71.4 with a 95% confidence interval [67.1, 75.6], well below the LES prediction of 100. The slope was not significant but because of the very limited range of values, the lack of significances is not that meaningful despite the fact that the estimated coefficient was nearly identical to the LES prescription (0.509 versus 0.500). Turning to Condition SB, the slope coefficient for the lower range of SB Sellers was significantly different from the LES prediction of zero -- a result also different from that observed in the isomorphic upper range for BS Buyers. Aggregated SB Sellers results exhibit moderate behavior with a y-intercept=70.8, more than 20% less than the LES prediction of 90. During the first block of 25 trials, the regression model produced an $R^2=0.52$ and a slope for the upper

TABLE 5-3. Regression Results, Varying-*k* Conditions

Dominating Player Treatment

	$0 \le v \le 40$		$40 \le v \le 200$	
BB Buyers	*Slope*	*Intercept*	*Slope*	Adj. R^2
Trials 1-25	0.981	-1.2	0.466	0.50
Trials 26-50	1.012	-1.6	0.294	0.37
Trials 1-50	0.972*	-1.2	0.385	0.42
LES	0.500	0.0	0.000	

	$0 \le v \le 20$		
BB Sellers	*Slope*	*Intercept*	Adj. R^2
Trials 1-25	0.284	26.8***	0.00
Trials 26-50	0.817	16.0***	0.04
Trials 1-50	0.546**	21.5***	0.01
LES	1.000	0.0	

	$0 \le v \le 160$		$160 \le v \le 200$	
SS Sellers	*Slope*	*Intercept*	*Slope*	Adj. R^2
Trials 1-25	0.113***	150.3***	0.734***	0.44
Trials 26-50	0.077***	158.9***	0.590***	0.55
Trials 1-50	0.093***	154.8***	0.671***	0.45
LES	0.000	180.0	0.500	

	$180 \le v \le 200$		
SS Buyers	*Slope*	*Intercept*	Adj. R^2
Trials 1-25	0.337	163.6*	0.00
Trials 26-50	0.671***	171.4	0.07
Trials 1-50	0.512***	167.5**	0.02
LES	1.000	180.0	

Balanced Power Treatment

	$0 \le v \le 110$		$110 \le v \le 200$	
BS Buyers	Slope	Intercept	Slope	Adj. R^2
Trials 1-25	0.868***	1.2	0.831	0.88
Trials 26-50	0.892***	2.4	0.858	0.92
Trials 1-50	0.879***	1.9	0.844	0.90
LES	1.000	0.0	0.000	

	$0 \le v \le 20$		
BS Sellers	*Slope*	*Intercept*	Adj. R^2
Trials 1-25	0.498	67.3***	0.01
Trials 26-50	0.455	76.1***	0.01
Trials 1-50	0.509	71.4***	0.01
LES	0.500	100.0	

	$0 \le v \le 90$		$90 \le v \le 200$	
SB Sellers	Slope	Intercept	Slope	Adj. R^2
Trials 1-25	0.353***	76.3***	0.775**	0.52
Trials 26-50	0.277***	66.7***	0.977***	0.80
Trials 1-50	0.330***	70.8***	0.868***	0.65
LES	0.000	90.0	1.000	

	$180 \le v \le 200$		
SB Buyers	*Slope*	*Intercept*	Adj. R^2
Trials 1-25	0.276	131.1	0.00
Trials 26-50	0.314	120.3	0.00
Trials 1-50	0.285	125.8*	0.00
LES	0.500	90.0	

* $p<0.05$ of the coefficient differing from zero
** $p<0.01$ of the coefficient differing from zero
*** $p<0.001$ of the coefficient differing from zero

[52] As mentioned earlier, the subject population for players in Condition SB were economics graduate students so

half of reservation values of 0.775. However, the model for the second block reveals considerable convergence toward the equilibrium and a superior fit improving to R^2=0.80 and the slope increasing to 0.977 (predicted 1.000). For the SB Sellers, the only significant coefficient across the 50 trials is the intercept at 125.8 that is far more aggressive that the LES predicted 90.

An interesting difference observed between the Dominating Player and Balanced Power treatments was manifest in the number of agreements reached compared to that predicted by equilibrium play. As shown in Table 5-4, players in the Dominating Player treatment made far *fewer* deals than predicted (an average of 8.1 fewer deals in Condition BB and 12.6 in Condition SS), whereas in the Balanced Power treatment players made *more* deals than predicted (4.8 and 3.2). The Dominating Player treatment predicts greater asymmetry between the players with the

TABLE 5-4. Deal Analysis, Varying-*k*.

	BB	SS	BS	SB
Predicted mean deals	46.9	46.2	24.0	25.5
Observed mean deals	38.8	33.6	28.8	28.7
Difference	17.3%	27.3%	-20.0%	-12.5%

strong players garnering most of the earnings leaving very little of the surplus to the weak players. By shifting the price-setting power to the weaker player in the Balanced Power condition, the predictions allocate a more equal division of the surplus to the players but are still largely biased to the information-advantaged player. The predicted number of deals for the Balanced Power treatment is nearly half that of the Dominating Player treatment. Even though

any noted difference between Conditions BS and SB must be qualified accordingly.

players in the Balanced Power treatment made fewer deals overall, they reached agreements more often than predicted.

(4) Simulation Analysis. Tables 5-5 through 5-8 list player earnings for each condition individually comparing observed data to simulated earnings had each buyer and seller mutually adhered to a truthful revelation strategy ($s=v_s$ and $b=v_b$) or a LES strategy under varying levels of k. The simulation used the identical random reservation value draws that occurred during the course of each experimental condition. Buyers in Condition BB (see Table 5-5) earned only 54% of what they should have obtained under the LES. Sellers, on the other hand, earned over 390%. Although subscribing to the LES would have generated 99.7% efficiency, players in Condition BB realized only 87.8%. Comparing actual player earnings to the LES predicted earnings yielded highly significant differences ($p<0.001$ for buyers and sellers individually). However, comparing the actual buyer earnings to those predicted by the LES when $k={}^1/_2$ yield no differences ($p=0.368$ for buyers and $p=0.995$ for sellers). Both buyer earnings and efficiency monotonically decrease in k. Conversely, as k decreases, predicted earnings for sellers increase illustrating the effect of how increased price-setting power should theoretically overcome an information disadvantage.

When the conditions are reversed conferring both an information advantage and price-setting power to the sellers in Condition SS, results are similar to those of Condition BB for the buyers. Table 5-6 reports sellers' earnings as only 62% of that predicted by the LES while buyers earned a commanding 213%. Achieved efficiency was also 12% lower at 76.9% instead of the 99.6% prediction. Using a two-tailed t-test, seller earnings differed significantly from LES

TABLE 5-5. Dominating Player Treatment: Condition BB Earnings Simulation

Subject	k=1 Observed	k=1 Truthful	k=1 LES	k=0.75 LES	k=0.5 LES	k=0.25 LES	k=0 LES
BB Buyer 1	1279.0	0.0	4102.0	3242.7	2407.7	1701.3	1109.5
BB Buyer 2	1175.0	0.0	4088.0	3243.0	2399.0	1695.8	1111.5
BB Buyer 3	2376.0	0.0	4097.0	3225.9	2396.7	1688.1	1098.5
BB Buyer 4	3198.0	0.0	4110.0	3250.7	2405.3	1701.3	1104.5
BB Buyer 5	1951.0	0.0	4064.5	3243.6	2395.3	1692.8	1102.5
BB Buyer 6	2082.0	0.0	4113.5	3245.3	2405.0	1698.4	1104.5
BB Buyer 7	2188.0	0.0	4088.0	3232.5	2383.7	1677.3	1097.5
BB Buyer 8	2656.0	0.0	4096.0	3229.7	2387.0	1685.8	1083.5
BB Buyer 9	2408.0	0.0	4079.5	3230.9	2386.0	1700.0	1104.5
BB Buyer 10	2809.0	0.0	4089.0	3230.1	2408.3	1694.4	1096.5
BB Seller 1	1397.0	3984.0	425.5	1119.6	1600.7	1727.7	1895.0
BB Seller 2	2214.0	5181.0	456.5	1254.8	1962.7	2535.9	2763.5
BB Seller 3	1597.0	4313.0	434.5	1138.9	1555.3	1893.5	2007.0
BB Seller 4	2115.0	4766.0	480.5	1314.4	1959.3	2253.3	2481.0
BB Seller 5	1915.0	4843.0	469.0	1251.4	1870.7	2267.0	2681.0
BB Seller 6	1739.0	4531.0	466.0	1220.5	1793.0	1887.1	2285.5
BB Seller 7	1739.0	4644.0	461.0	1204.5	1600.0	1867.7	2364.0
BB Seller 8	1922.0	4082.0	446.5	1172.8	1858.0	2171.8	1986.5
BB Seller 9	1127.0	4408.0	472.5	1255.1	1757.7	1737.1	1995.0
BB Seller 10	2172.0	4893.0	485.5	1377.5	1986.7	2247.6	2394.5
Total	40059	45645	45525	44684	41918	37524	33866
Mean Buyers	2212	0	4093	3237	2397	1694	1101
Mean Sellers	1794	4565	460	1231	1794	2059	2285
Efficiency	87.8%	100.0%	99.7%	97.9%	91.8%	82.2%	74.2%

predictions but once again yielded no difference when compared to earnings predicted with $k=1/2$. Efficiency and earning predictions monotonically decreased in k for the sellers. Observed efficiency was also worse than any of the simulated predictions due to the aggressiveness of the information-disadvantaged buyers refusing to be "pushed up."

Tables 5-7 and 5-8 report results from the Balanced Power treatment. Observed efficiency in Condition BS (see Table 5-7) turned out to be slightly better (2.7%) than the prediction. Despite the fact that the LES predicted a larger share of the surplus for the players

TABLE 5-6. Dominating Player Treatment: Condition SS Earnings Simulation.

Subject	k=0 Observed	k=0 Truthful	k=0 LES	k=0.25 LES	k=0.5 LES	k=0.75 LES	k=1 LES
SS Buyer 1	490.0	4233.0	450.5	1211.3	1594.7	1807.3	2184.5
SS Buyer 2	1176.0	4944.0	433.5	1148.7	1724.7	2144.9	2552.5
SS Buyer 3	971.0	4307.0	420.0	1137.3	1692.3	1803.3	2279.5
SS Buyer 4	1039.0	4923.0	469.5	1277.1	1901.0	2240.4	2574.5
SS Buyer 5	888.0	4723.0	467.0	1216.1	1766.7	2175.4	2576.5
SS Buyer 6	888.0	4747.0	467.5	1208.8	1842.0	2088.1	2282.0
SS Buyer 7	1234.0	4378.0	440.5	1164.7	1798.3	2160.2	2462.5
SS Buyer 8	545.0	4364.0	446.0	1132.5	1615.7	1969.3	2390.5
SS Buyer 9	1183.0	4652.0	463.0	1277.7	1898.3	2170.6	2382.5
SS Buyer 10	1242.0	4844.0	477.5	1232.7	1806.7	2165.1	2558.5
SS Seller 1	2822.0	0.0	4133.0	3311.5	2497.3	1814.0	1189.0
SS Seller 2	2472.0	0.0	4152.5	3314.7	2511.0	1815.3	1186.0
SS Seller 3	2446.0	0.0	4140.5	3304.9	2503.3	1814.9	1184.0
SS Seller 4	2498.0	0.0	4144.0	3285.1	2470.7	1770.7	1136.0
SS Seller 5	2744.0	0.0	4129.5	3309.7	2505.3	1815.7	1183.0
SS Seller 6	2369.0	0.0	4147.0	3301.7	2510.0	1806.3	1175.0
SS Seller 7	2618.0	0.0	4133.5	3314.5	2511.7	1821.7	1189.5
SS Seller 8	2742.0	0.0	4157.5	3301.3	2494.0	1798.6	1162.0
SS Seller 9	2631.0	0.0	4144.0	3292.3	2493.7	1802.9	1168.5
SS Seller 10	2477.0	0.0	4124.5	3311.4	2496.7	1821.3	1195.5
Total	35475	46115	45941	45054	42634	38806	36012
Mean Buyers	966	4611	454	1201	1764	2072	2424
Mean Sellers	2582	0	4141	3305	2499	1808	1177
Efficiency	76.9%	100.0%	99.6%	97.7%	92.5%	84.2%	78.1%

with the price setting power (sellers), the information-advantaged players (buyers) fared better. Consistent with both conditions of the Dominating Player Treatment in Tables 5-5 and 5-6, the price-setting player's (seller) actual earnings are significantly different than that predicted by the LES with k=0 ($p<0.001$), but do not differ from earnings that would have been obtained under identical conditions and $k=1/2$ (p=0.228). The information-advantaged players also commanded a larger share of the surplus (53%) despite predictions that price-setting players (sellers) do better

TABLE 5-7. Balanced Power Treatment: Condition BS Earnings Simulation.

Subject	k=0 Observed	k=0 Truthful	k=0 LES	k=0.25 LES	k=0.5 LES	k=0.75 LES	k=1 LES
BS Buyer 1	1870.0	4609.0	1109.5	1701.3	2407.7	3242.7	4102.0
BS Buyer 2	1875.0	4569.0	1177.5	1784.1	2508.7	3372.6	4088.0
BS Buyer 3	1799.0	4527.0	1162.5	1775.0	2505.7	3355.9	4097.0
BS Buyer 4	1603.0	4614.0	1116.5	1736.8	2464.0	3331.7	4110.0
BS Buyer 5	2154.0	4573.0	1163.0	1775.8	2500.0	3368.6	4064.5
BS Buyer 6	1787.0	4600.0	1104.5	1698.4	2419.7	3281.9	4113.5
BS Buyer 7	2023.0	4518.0	1113.0	1715.1	2443.0	3311.9	4088.0
BS Buyer 8	1986.0	4557.0	1083.5	1685.8	2395.7	3256.3	4096.0
BS Buyer 9	1965.0	4518.0	1112.0	1730.7	2439.3	3305.9	4079.5
BS Buyer 10	2076.0	4560.0	1162.5	1783.0	2518.7	3360.9	4089.0
BS Seller 1	1244.0	0.0	1973.5	1854.3	1723.0	900.3	117.0
BS Seller 2	2201.0	0.0	2862.0	2648.5	2017.3	947.0	117.0
BS Seller 3	1445.0	0.0	2105.5	1997.0	1610.0	852.2	120.5
BS Seller 4	1950.0	0.0	2580.0	2362.6	2014.7	956.6	126.0
BS Seller 5	2076.0	0.0	2778.0	2376.3	1923.3	926.1	123.5
BS Seller 6	1982.0	0.0	2383.0	1991.8	1846.3	943.7	124.0
BS Seller 7	1352.0	0.0	2454.0	1964.4	1643.3	860.0	130.0
BS Seller 8	1384.0	0.0	1986.5	2199.1	1911.3	869.5	124.0
BS Seller 9	1519.0	0.0	2087.5	1833.2	1804.3	854.3	127.0
BS Seller 10	1869.0	0.0	2394.5	2281.3	2032.0	968.1	123.5
Total	36160	45645	34909	38894	43128	42267	42160
Mean Buyers	1914	4565	1130	1739	2460	3319	4093
Mean Sellers	1702	0	2360	2151	1853	908	123
Efficiency	79.2%	100.0%	76.5%	85.2%	94.5%	92.6%	92.4%

(predicted 68%). The information advantage seems to have a strong effect in overcoming the disadvantage of "veto-only" power over the trade price.

Overall efficiency in Condition SB was almost exactly what was predicted as shown at the bottom to Table 5-8. As noted in Condition BS, the information-advantaged players (sellers) outperformed the price-setting players with the information-disadvantage against the LES predictions. Remarkably, the earnings of the price-setting empowered players (buyers) also differed from LES predictions with k=1 (p<0.001) but did not differ from those predicted

TABLE 5-8. Balanced Power Treatment: Condition SB Earnings Simulation

Subject	k=1 Observed	k=1 Truthful	k=1 LES	k=0.75 LES	k=0.5 LES	k=0.25 LES	k=0 LES
SB Buyer 1	1247.0	0.0	2184.5	1807.3	1594.7	1211.3	450.5
SB Buyer 2	1889.0	0.0	2552.5	2144.9	1724.7	1148.7	433.5
SB Buyer 3	1505.0	0.0	2279.5	1803.3	1692.3	1137.3	420.0
SB Buyer 4	1831.0	0.0	2574.5	2240.4	1901.0	1277.1	469.5
SB Buyer 5	1647.0	0.0	2576.5	2175.4	1766.7	1216.1	467.0
SB Buyer 6	1659.0	0.0	2282.0	2088.1	1842.0	1208.8	467.5
SB Buyer 7	1645.0	0.0	2462.5	2160.2	1798.3	1164.7	440.5
SB Buyer 8	1435.0	0.0	2390.5	1969.3	1615.7	1132.5	446.0
SB Buyer 9	1862.0	0.0	2382.5	2170.6	1898.3	1277.7	463.0
SB Buyer 10	1717.0	0.0	2558.5	2165.1	1806.7	1232.7	477.5
SB Seller 1	1577.0	4615.0	1189.0	1814.0	2497.3	3311.5	4133.0
SB Seller 2	2045.0	4650.0	1186.0	1815.3	2511.0	3314.7	4152.5
SB Seller 3	1741.0	4624.0	1184.0	1814.9	2503.3	3304.9	4140.5
SB Seller 4	2110.0	4521.0	1136.0	1770.7	2470.7	3285.1	4144.0
SB Seller 5	1974.0	4623.0	1183.0	1815.7	2505.3	3309.7	4129.5
SB Seller 6	1854.0	4624.0	1175.0	1806.3	2510.0	3301.7	4147.0
SB Seller 7	1931.0	4658.0	1189.5	1821.7	2511.7	3314.5	4133.5
SB Seller 8	1758.0	4591.0	1162.0	1798.6	2494.0	3301.3	4157.5
SB Seller 9	2288.0	4589.0	1168.5	1802.9	2493.7	3292.3	4144.0
SB Seller 10	2241.0	4620.0	1195.5	1821.3	2496.7	3311.4	4124.5
Total	35956	46115	36012	38806	42634	45054	45941
Mean Buyers	1644	0	2424	2072	1764	1201	454
Mean Sellers	1952	4612	1177	1808	2499	3305	4141
Efficiency	78.0%	100.0%	78.1%	84.2%	92.5%	97.7%	99.6%

under $k=1/2$ (p=0.114). This is a remarkably robust finding across all four conditions. The information-advantaged players (sellers) commanded the largest share of the surplus (54%) in equal proportion to the buyers in Condition BS. The overall results provide additional support that an information advantage can overcome a co-bargainer's price-setting power advantage.

(5) Varying-k Discussion. Previous experimental research on the bilateral bargaining game of incomplete two-sided information when one player has a distinct information advantage has consistently shown that the information-advantaged players effectively use their

information advantage to garner a larger-than-predicted portion of the surplus. However, when the traditional midpoint trading rule was altered giving one of the parties exclusive price-setting power, the Information Disparity Hypothesis proposed by RDS falls short. Furthermore, in all previous studies, the LES received generous support despite information asymmetry. Conferring an exclusive price-setting advantage to either player (regardless of whether or not he is information-advantaged) produced an equilibrium prediction that the price-setting empowered player would earn a larger share of the surplus. This prediction was also rejected. Although the information-advantaged players behaved far less aggressively than in previous studies and less aggressive than the LES, they still were able to use the information advantage to gain a larger-than-predicted portion of the surplus.

The most surprising and robust finding in the present experiments was not the deviation from the LES at the extreme values of k, but instead the consistently high degree of similarity between earnings of the price-setting player to the predictions of an identical game where the midpoint rule was employed. It is as if the price-setting players developed a belief regarding what a "fair" trade price would have been in a split-the-difference environment and then submitted an offer derived from it. Players possibly recognized the gross asymmetry of price-setting power, perceived it to be "unfair" and acted in ways similar to those often reported in voluminous ultimatum bargaining game literature (Rubenstein, 1982; Hoffman et at, 1994 and 1996).[53] The finding is robust regardless whether or not a player had an information advantage when unilaterally setting the trade price.

[53] The bilateral bargaining mechanism of the present study differs from ultimatum bargaining games in several important ways: (1) it is sequential, not simultaneous; (2) the size of the surplus is common knowledge and known to exist with certainty; (3) Nash equilibrium solutions are obvious and unique whereas the LES in only one of many and quite unintuitive.

CHAPTER VI: LEARNING

A. INTRODUCTION

A fundamental question addressed in most experimental investigations of game theoretic models is to what extent behavior supports predictions derived from the Nash equilibrium solution concept and its subsequent refinements. The bargaining studies reported here are no exception. The LES has been previously established as the static model of choice to which performance has been compared, given its very attractive attributes (simplistic, linear uniqueness) despite the existence of many other equilibria for this particular mechanism. However, the multiplicity of equilibria can raise doubts about the usefulness of general equilibrium theory to make predictions about human behavior in similar strategic situations, especially when deviations from expectations cannot be readily explained. When players' behavior converges to an unexpected strategy set, it is equally feasible that they have coordinated their actions by establishing common knowledge of the rules of the game, rationality of each other, and the payoff functions. Given these conditions, behavior need not correspond to any theoretical equilibrium at all. Such a situation poses serious problems for theoretical refinements. Moreover, it has been well established in the extant literature as well as in the data reported in this manuscript that the Nash equilibrium can only be sustained in very simple games. However, when games are repeated allowing players to experience the mechanism as well as gather information about their opponents, behavior changes as experience is gained, often in the direction of a particular equilibrium. If the game is not transparent, iteration is necessary, though not a sufficient condition for the emergence of equilibrium play. For these reasons, it is both

important and necessary that the dynamic aspects of the data be analyzed to account for the variation and convergence of behavior over time. Mathematical expression of the relationships in the data can be expressed in a system of equations creating a model capable of capturing regularities in the data, which is necessary to formulate empirical laws about behavior.

B. Historical Perspective of Learning Models

(1) The Early Years. The mathematical learning model approach dates back to the early 20th century in psychology with experiments based on the assumptions that acquisition takes place at a constant rate but that forgetting is proportional to the amount learned. Thurstone (1919) first attempted to provide serious rationale for the learning curve. He assumed that the probability of an act on any trial being successful is equal to the proportion of successful acts to total possible acts. The result was articulated by Blackburn in the exposition of his Law of Effect, which states that there exists a probability that if an act is successful it will be retained, and with the same probability, if unsuccessful, it will be eliminated (1936). Bush and Mosteller's (1955) and Estes' (1950) pioneering efforts initiated the development of modern mathematical learning theory. Although mathematical learning theory gained increasing attention, until the 1960s learning models focused exclusively on individual choice behavior within the domain of psychology Due primarily to the work of Suppes and Atkinson (1960) and Siegel and Fouraker (1960), the experimental paradigm was enlarged to encompass interactive-decision making.

(2) Modern Modeling Approaches. The current literature on learning theory can be roughly classified into three groups: reinforcement, belief, and rule-based models. Reinforcement learning (Thorndike, 1898; Bush and Mosteller, 1955; Roth and Erev, 1995; Erev and Roth, 1998) emanated from the psychology perspective where most of the work centered on human and animal subjects, whereas belief (Brown, 1951; Fudenberg and Levine, 1998) and rule learning (Stahl, 1996) developed primarily from economics. The primary debates between these approaches focus on what information is relevant in fostering adaptive behavior over time. Choice reinforcement follows from the Law of Effect where strategies that have resulted in successful outcomes are chosen more often. Thus, the primary source of information is an individual's own payoff associated with a particular strategy. Belief models, on the other hand, look not to individual outcomes as the source of information, but rather to the belief structure about the other players that resulted in the selection of a particular strategy. Based on the observed actions of others after engaging in a play of the game, a player's beliefs will be updated if the actions were not what was expected; otherwise, a player's belief structure remains unchanged. The major point of departure in the belief models from the reinforcement models is that the player calculates expected earnings not on his outcomes, but rather on his beliefs about the other n-1 players. Fictitious play, proposed by Brown and Robinson (1951), provides the theoretical underpinnings of belief-based models.

Work by Roth and Erev (1995; 1998, hereafter RE) has been instrumental in demonstrating how a family of adaptive learning models can accurately account for the trial-to-trial variability in which players increase the probability of playing pure strategies that

have met with success in previous periods. Their basic model assumes each player n has an initial propensity to play his k^{th} pure strategy, given some number $q_{nk}(1)$, which is a parameter that must be estimated from the observed data. If player n plays his k^{th} pure strategy at time t and receives a payoff x, then the propensity to play strategy k is updated by setting $q_{nk}(t+1) = q_{nk}(t) + x$ while for all other pure strategies j, $q_{nj}(t+1) = q_{nj}(t)$. The probability $p_{nk}(t)$ that player n plays his k^{th} pure strategy at time t is given by $p_{nk}(t) = q_{nk}(t) / \Sigma q_{nj}(t)$. RE have generally concluded that there appears to be classes of games for which observed learning behavior is primarily a property of the game rather than of the particular learning process of the players. The adaptive models have also been shown to be very sensitive to initial conditions; however, their emphasis has been on intermediate term results of the model rather than its asymptotic properties. Even though various RE models have considerably different asymptotic properties, in the intermediate term each yields very similar results. RE have also shown conclusively that the same dynamic models can make different predictions for different games.

At the other extreme, Camerer and Ho (1999; hereafter CH) responded to RE advocating a more general approach to learning. CH argue that their experience-weighted attraction model (EWA) makes a significant contribution to the learning literature as they "bridge the gap" between these two theories by demonstrating that choice-reinforcement and belief-based models are not philosophically different approaches. Rather, they are special cases of a general model of learning--EWA. The CH approach is embedded in a philosophy that learning is a general phenomenon that can be explained with a sufficiently complex model. The EWA model contains fourteen parameters raising doubt not only

about its psychological interpretability, but also its power to describe all learning with parameter values customized to each data set. Additionally, the results reported are always on aggregate data. Although the professed focus is on an "individual" learning model, CH consistently only model group data, not individuals.

(3) Model Comparison. When quantitative theories and models become important in science, there is a shift in emphasis from testing hypotheses to estimating parameters. Feltovich (2000) provided an unbiased and fair treatment of learning model comparisons between the predominant reinforcement-based models of RE and belief-based models inherent in the CH approach. Using a new experiment a baseline for testing each of the models, the reinforcement-based approach outperformed the belief-based models given the initial testing criteria. These criteria assumed random propensities (reinforcement) and random weights (belief) and used mean-squared deviation (MSD), log likelihood (ln(L)) and proportion of inaccuracy (POI) as the measures of "goodness" in assessing the models. However, when the initial criteria were adapted by using data from the first trial as an estimate for initial conditions, one of the parameterizations of the belief-based model did better than the rest. It is important to note that not only did the belief-based model incorporate two free parameters (λ and δ) but there was also no a priori way of justifiably selecting the proper parameters to yield superior results. Feltovich notes that if an assumption is made that δ should take on a positive value reflecting more weight on recent opponent actions and less weight on earlier actions, then no parameterization of the belief-based model could have outperformed the reinforcement-based model. The inclusion of the

free parameters and the unintuitive interpretation of the "best" parameters is clearly problematic for the belief-based approach.

In addition to testing the models on his own new data set, Feltovich adopted the RE philosophy of "tying his hands" and using other's data sets. To be fair, he selected two data sets reported on by RE and two data sets reported on by CH. Not surprisingly, the reinforcement-based model performed best on the RE data sets. However, this is only when the evaluation criterion is MSD. When considering POI or *ln*(L), the belief-based model did better. Feltovich concluded that the reinforcement-model tended to do better on data sets with many trials whereas the belief-model performed better on smaller samples.

Camerer, Hsia and Ho (CHH, 2002) have recently attempted to directly compete the DSR reinforcement model (to be described extensively in the next section) to the EWA specifically on data from a two-person bargaining mechanism. The CHH approach to modeling behavioral dynamics in the bilateral bargaining game of incomplete information is problematic for several reasons.

1. *The EWA focuses on the group data, not the individual.* The CHH approach grossly deviates from the fundamental philosophy underlying the DSR approach--the reinforcement-based adaptive learning model was developed as an individual learning model, not as an aggregate model. Thus, it is no surprise that DSR's data yielded lower coefficients of determination and higher root mean squared errors when collapsed as reported by CHH.
2. *The EWA necessitates extreme discretization of the strategy space.* Not only does the EWA approach focus exclusively on the aggregate results but also it requires that

the already discrete data be discretized further into arbitrarily determined intervals. This action was driven by a concern for parsimony, since using the discrete data as reported by DSR would necessarily have increased the number of parameters in the EWA model considerably.

3. *Lackluster performance.* Despite the contorted manipulations to facilitate the CHH comparison, the EWA still did not significantly outperform the DSR model. This is surprising since the EWA model used ten parameters whereas the DSR model only used four. Competing the models as formulated, DSR outperforms EWA with fewer than half the parameters and without making many assumptions subscribing to the most basic principles of scientific endeavor (e.g. Ockham's Razor – the simplest explanation is superior).
4. *Parsimony.* Unquestionably, the more parameters that are added to a model, the better the model can account for the variation of the data. CHH avoided the parsimony issue by refraining from fitting the EWA to individual players. Although such analysis seems obvious, it would necessarily subscript each parameter, increasing the total number of parameters by a magnitude.

Based on the CHH application of EWA to data of the bilateral bargaining mechanism and the shortcomings noted above, it is deemed inappropriate and unnecessary to attempt to manipulate data collected for the present studies to be able to make it compatible with the EWA model. Instead, the approach of the following sections will be to evaluate the generality and applicability of the DSR learning model focusing on dynamics of play and individual differences as a robust test of its viability.

C. A Reinforcement-Based Adaptive Learning Model for Two-Person Bargaining Under Incomplete Information

The reinforcement-based adaptive learning model introduced by DSR (1998) and modified by SDR (2000) is tested to assess its generality in accounting for trial-to-trial variability of bids and asks in several bargaining mechanisms. The model strives for parsimony using only four parameters comprised of both a linear function and a conjoined exponential function. This model has repeatedly demonstrated its ability to closely approximate behavior of information-advantaged players with similar, although somewhat weaker results for information-disadvantaged players (RDS and SDR). The model makes no probabilistic assumptions nor does it require the estimation of initialization values for the parameters. Its emphasis is on accounting for the learning of individuals. The goodness of fit for the model is measured by both R^2 estimating the linear approximation of the model fit and the root mean squared error (RMSE) between observed and predicted data. Past experience is reflected in the model by a free parameter (y in the buyer's model and z in the seller's model) that changes the entire shape of the individual bid/offer function. If a trade is successful, then the buyer's (seller's) function in decreased (increased). In the event that an agreement is not reached but feedback indicates that a deal could have been made but for greed, then the buyer's (seller's) function is increased (decreased). Alternatively, if an agreement is not made and the player has insufficient information to ascertain that a transaction was realizable, then the function remains unchanged. A discount parameter is also incorporated into the model to depreciate the effect of the free parameter over time.

(1) The DSR Model. Stated formally, let the following system of equations represent the learning model for the buyer:

$$b_t = Min\{(v_b)_t, y_{t-1}[1 - exp[-(v_b)_t / y_{t-1}]]\} \qquad t = 1, 2, 3\ldots..T \qquad (6.1)$$

$$\text{If } b_t \geq s_t: \quad y_t = y_{t-1}[1 - w^{+}_{y,t}((v_b)_t - p_t)] \qquad \text{where } p_t = (b_t + s_t)/2$$
$$w^{+}_{y,t} = (1 - d_y)\, w^{+}_{y,t-1} \qquad \text{where } 0 \leq d_y \leq 1 \qquad (6.2)$$

$$\text{If } b_t < s_t: \quad y_t = y_{t-1}\{Max\,[1, 1 + w^{-}_{y,t}((v_b)_t - s_t)]\}$$
$$w^{-}_{y,t} = (1 - d_y)\, w^{-}_{y,t-1} \qquad \text{where } 0 \leq d_y \leq 1 \qquad (6.3)$$

and the learning model for the seller:

$$s_t = Max\,\{(v_s)_t, \beta_s - z_{t-1}[1 - exp[-[(\beta_s - (v_s)_t)/z_{t-1}]]]\} \quad t = 1, 2, 3\ldots..T \qquad (6.4)$$

$$\text{If } b_t \geq s_t: \quad z_t = z_{t-1}[1 - w^{+}_{z,t}(p_t - (v_s)_t)] \qquad \text{where } p_t = (b_t + s_t)/2$$
$$w^{+}_{z,t} = (1 - d_z)\, w^{+}_{z,t-1} \qquad \text{where } 0 \leq d_z \leq 1 \qquad (6.5)$$

$$\text{If } b_t < s_t: \quad z_t = z_{t-1}\{Max\,[1, 1 + w^{-}_{z,t}(b_t - (v_s)_t)]\}$$
$$w^{-}_{z,t} = (1 - d_s)\, w^{-}_{z,t-1} \qquad \text{where } 0 \leq d_z \leq 1 \qquad (6.6)$$

The parameters are defined as follows.[54] On any trial t for up to T trials, a buyer and seller respectively draw reservation values $v_{b,t}$ and $v_{s,t}$ and submit a bid (b_t) and ask (s_t) simultaneously. The free parameters y (buyer) and z (seller) affect the shape of the exponential functions for each of the players, which identify the extent of aggressiveness of the strategies. Smaller values of y and z represent more aggressive bidding. As defined in earlier chapters, β_s is the upper limit of F, the seller's distribution, and p is the trade price. The parameters w^+ and w^- affect the change induced by positive and negative outcomes, respectively, and the parameter d represents the discount or depreciation of the effects over time.

[54] For internal notational consistency throughout this manuscript, some of the model parameters have been relabeled from the original exposition of the model.

(2) The Two-stage Refinement.

Parameter estimates from the DSR model on data collected from the two-stage mechanism turned out to be considerably worse than results from data from single-stage games. Previous analysis has shown that players reveal information during stage 1 play despite it being a dominated strategy. The reason for this was clear: any dynamic model must account for the dependence of stage 2 offers on stage 1 offers. The two-stage game differs from the single-stage game since a player may use information gained from a co-bargainer's stage 1 offer in formulating his stage 2 offer. The modified two-stage learning model for the buyer takes a similar form as the single-stage model with a single exception. During stage 2 play, the model incorporates the seller's stage 1 offer, provided no agreement was reached during stage 1 ($b_{t,1}<s_{t,1}$). If the seller's stage 1 offer is less than the buyer's reservation value ($s_{t,1}<(v_b)_t$), then the buyer will use the seller's stage 1 offer as the stage 2 bid ($b_{t,2}=s_{t,1}$). Otherwise, the buyer bids in accordance with the single-stage model. This model is conservative. Surely the buyer knows that the seller probably asked too much and that, in all likelihood, she will ask less in the second-stage ($s_{t,2}<s_{t,1}$). However, they buyer decides to play it safe and set $b_{t,2}=s_{t,1}$. The same logic applies to the seller. The modified model used for the buyer in a two-stage mechanism is as follows:

If $(v_b)_t \geq s_{t,1}$: $\quad b_{t,2}=s_{t,1}$

$$\text{Otherwise,} \qquad b_{t,2} = Min\{\,(v_b)_t\,, y_{t-1}[1 - exp(-\,(v_b)_t\,/y_{t-1})]\} \tag{6.7}$$

and the similar refinement to the seller's model:

If $(v_s)_t \leq b_{t,1}$: $\quad s_{t,2}=b_{t,1}$

$$\text{Otherwise} \qquad s_t = Max\,\{(v_s)_t, \beta_s - z_{t-1}[1 - exp[-[(\beta_s - (v_s)_t)/z_{t-1}]]]\} \tag{6.8}$$

Implementation of these refinements into the DSR learning model for two-stage games yields results similar, and in some cases, superior to those of the single stage-games.

(3) Estimation Procedure. Using the generally accepted methods of partial data[55] and least squares, parameters for the learning model were estimated for each subject separately for all studies and results aggregated by condition. Maximizing R^2 of the observed offers for Trials 1-30 of the best fitting linear and exponential function was the criterion used to fit the parameters. Once the parameters were estimated for a particular subject, the fitted model was tested using the remaining twenty out-of-sample trials[56] to ascertain the validity of the estimates. Evaluation of the individual fitted parameters focuses on two criteria: the square root of the mean squared error (RMSE) and the coefficient of determination (R^2) scores of the out-of-sample data.

(4) Results: Moderate Information Asymmetry

(a) Buyer Model. (See Table 6-5 for model results across treatments.)

(i) Baseline Mechanism. Parameter estimates for the Baseline Condition are reported in Table 6-1. Parameter comparisons between the Baseline buyers and buyers from DSR Experiment 1 (Table 6-5) show no significant differences in learning (p=0.129; t=1.59). Only estimates for the w^+ parameter differed between the two studies. Subjects 3, 9, and 14 made several offers above their reservation values which resulted in lower R^2 and higher RMSE values compared to the other subjects who observed individual rationality and

[55] Uses part of the data set to estimate parameter values leaving the remaining portion to validate the estimates.
[56] With the singular exception of Sophisticated players in the two-stage study which estimated parameters on the first 15 trials and then tested them on the remaining 10 trials.

never bid above their respective valuations. A value of 1000 for the free parameter, *y*, for Subject 7 is a result of consistent truth-telling behavior. Remarkably, parameter estimates for the Baseline buyers yielded nearly the same fit as in the original DSR study. The mean R^2 for the first thirty trials was $\overline{R^2}=0.89$ and it improved to $\overline{R^2}=0.94$ when tested on the remaining twenty out-of-sample trials. The RMSE for both portions of the partial data samples were also significant improvements over the results of DSR Experiment 1.

(ii) Bonus Mechanism. Parameter estimates for the Bonus conditions are reported in Tables 6-2a, 6-2b, and 6-2c. An analysis of variance of the learning parameter (*d*) yielded no significant differences at $\alpha=0.05$ for any of the bonus conditions. However, values of the learning parameter, *d*, were slightly larger than in the Baseline condition indicating a more rapid degree of learning with bonus implementation. The difference in the rate of learning was significantly faster in the Partial Bonus condition compared to both the Baseline ($p=0.023$; $t=2.48$) and Full Bonus condition ($p=0.001$; $t=4.02$). All buyers in the Partial Bonus condition achieved out-of-sample $R^2>0.90$ with the exceptions of Buyers 10 and 18, although both still yielded an acceptable fit of $R^2=0.83$ and $R^2=0.74$, respectively. Buyer 10 continued to reformulate his offer strategy beyond Trial 30 (still learning) while Buyer 16 made two offers below her reservation value violating individual rationality. Additionally, Buyers 3 and 13 each yielded larger RMSE values caused by making offers below valuation. In the Full Bonus condition, the smallest R^2 for any buyer was $R^2=0.74$ and the highest RMSE was 23.77, both induced by irrational bidding. The R^2 fit for Subject 8 decreased from $R^2=0.95$ to $R^2=0.83$ primarily due to learning beyond Trial 30, particularly for the upper-range of reservation values. Learning in the Reframed Full Bonus condition

progressed at much the same pace as in the Partial and Full Bonus conditions. The free parameter values also indicate that players in the Full Bonus condition were much more aggressive than observed in either the Partial Bonus or Baseline experiments. However, as predicted, the model yielded the largest estimated value of y for the Reframed Full Bonus condition indicating much less aggressive bidding (65% of y values for Reframed Full Bonus buyers exceed 200). The only subject who stood out in the Reframed Full Bonus condition was Buyer 10 whose R^2 value decreased from R^2=0.94 to R^2=0.59 as he also continued to change his strategy dramatically after Trial 30 from following a predominantly truthful revelation strategy to a considerably more aggressive strategy. Despite the few and distinctly minor exceptions mentioned above, the DSR buyer model performed exceeding well across conditions of the Bonus Mechanism data as in the Baseline study producing average R^2 values from $0.93 \leq \overline{R}^2 \leq 0.95$ and RMSE$\leq$9.3. As noted in previous studies, values of w^- exceeded those of w^+ indicating the greater sensitivity to losses than gains consistent with the predominant cognitive theories of decision-making (ala Kahneman and Tversky's Prospect Theory, 1979).

(iii) Two-stage Mechanism. Parameter estimates for the Two-stage study are reported in Tables 6-3a, 6-3b, and 6-3c. Only Sophisticated buyers in the Two-stage mechanism differed significantly with respect to the learning parameter, d, from the Baseline results at α=0.05 (t=2.28) whereas Inexperienced and Experienced subjects exhibited no differences (p=0.131 and p=0.135 respectively). Overall fit of the buyer learning model across conditions was excellent with R^2 values narrowly ranging from $0.91 \leq R^2 \leq 0.93$ and RMSE values ranging between 8.76 and 12.26. Buyers 6, 35, and 42 were the only subjects

with fewer than thirty stage 2 offers. Buyer 1 made a single bid (considerably) above his reservation value resulting in a lower R^2 and higher RMSE. Buyer 17 also made two irrational stage 2 bids in later trials resulting in a poorer fit of the model. The most notable difference between the two-stage conditions is evident by directly comparing values of the learning parameter, *d*. Only two buyers in the Sophisticated condition yielded a positive value for *d*-the other demonstrated no learning across trials. Thirty-five percent of Inexperienced buyers and 70% of Experienced players individually yielded d=0. The free parameter, *y*, estimated for the Sophisticated buyer was also half that of the Inexperienced or Experienced conditions (y=154 versus y=347 and y=397, respectively) illustrating the extreme aggressiveness of the Sophisticated players. Estimated mean values across subjects for the loss parameter, w^-, also greatly exceeded those of the gain parameter, w^+ although the differences were more pronounced for the less sophisticated players.

(b) Seller Model. (See Table 6-5 for model results across treatments.)

(i) Baseline Mechanism. Parameter comparison between the Baseline sellers and sellers from DSR Experiment 1 (Table 6-5) showed no significant differences in learning (p=0.733; t=0.35). There were also no differences between estimated values for any of the parameters at α=0.10 (Table 6-1). Individual results were dramatically more varied for the information-disadvantaged sellers compared to that of buyers. The range of out-of-sample R^2 values for the information-disadvantaged sellers ranged from R^2=0.03 to R^2=1.00. Sellers exhibited considerably more offers in violation of individual rationality, which partly accounted for poorer performance of the seller model. Sellers 25 and 26 were the most prominent violators yielding RMSE=13.50 and RMSE=10.96. Seller 29 made three

excessively strategic offers during the last 20 trials resulting in an R^2=0.03 and RMSE=22.61. The overall means of $\overline{R}^2$ =0.75 and $\overline{\text{RMSE}}$ =8.90 were slightly worse than results reported by DSR. Both the loss parameter, w^-, and the gain parameter, w^+, were nearly identical in magnitude and proportion to DSR Experiment 1 reported estimates following the consistent pattern of $w^- >> w^+$ by a magnitude.

(ii) Bonus Mechanism. Pairwise comparisons between both the Partial (Table 6-2a) and Full Bonus (Table 6-2b) condition with results from the Baseline sellers (Table 6-1) revealed no differences in learning (d) with a Bonferroni corrected α=0.05 (t=0.92 and t=1.25). The difference between the Reframed Bonus (Table 6-2c) condition and the Baseline sellers revealed that learning was much more prominent in the Reframed Bonus condition (p=0.052). Model results for individual subjects ranged from overall fits as low as R^2=0.05 and as high as R^2=0.99. Overall $\overline{R}^2$ =0.74 for the bet fitting mean estimates and $\overline{R}^2$ =0.80 for out-of-sample data. RMSE values ranged from 3.11 to 21.17. The seller model performed well in most cases, consistent with results reported in DSR Experiment 1. The primary exception was exhibited by Seller 34 because this particular subject demonstrated continually changing offer strategies throughout the 50 trials being very aggressive, then truthful, then aggressive almost invariant of reservation value with an R^2=0.05. Low values for the free parameter, z, indicated aggressive behavior by the sellers as a group, despite the fact that the partial bonus was intended to induce precisely the opposite effect. The mean value of z=105 which was far smaller than both the Baseline (z=188) and DSR Experiment 1 (z=345). Individual estimates for $\bar{w}$ were rather consistent across

players indicating similar reaction to losses, although estimates for w^+ were much more varied and much smaller. Parameter estimates were very similar for sellers in the Full and Reframed Full Bonus conditions with the notable difference in the mean free parameter value. The Reframed Full Bonus condition yielded z=283, whereas the Full Bonus condition yielded a value less than half of that (z=111), indicating that the reframing of the instructions had a profound effect in attenuating the aggressiveness of the sellers. This is evident in the individual plots of the decisions (compare Figures 3-3b and 3-4b). Overall fit of the seller model produced an R^2=0.75 and R^2=0.78 for in-sample data improving to R^2=0.86 for the out-of-sample data for the Full Bonus condition and remained relatively constant for the Reframed Full Bonus condition. Although not as good of a fit as the buyer model, the seller model fit well just as reported in previous studies.

(iii) Two-stage Mechanism. The modified seller model produced impressive results for the two-stage mechanism with an overall mean R^2=0.84 in-sample and R^2=0.75 out-of-sample.[57] There were no significant differences between any of the two-stage condition sellers and sellers in the Baseline condition with respect to rates of learning. Inexperienced sellers demonstrated the smallest learning effects and Sophisticated sellers the largest. Inexperienced sellers were the least aggressive yielding a free parameter value z=156 and Experienced sellers the most aggressive with z=91. Values for the gain and loss parameters were nearly identical between conditions with the exception that Experienced sellers tended to be more sensitive to gains. Consistent with all previous estimation of the

[57] R^2 would have improved to 0.80 with the elimination of Seller 32 contributing a R^2=0.04.

TABLE 6-1. Learning Model Results, Baseline Condition

	Parameters				Trials 1-30		Trials 31-50	
Buyer	*d*	w^+	w^-	*y*	R^2	*RMSE*	R^2	*RMSE*
1	2.57E-01	1.00E-04	1.37E-02	130	0.93	7.04	0.96	6.40
2	2.00E-01	1.00E-05	1.00E-03	120	0.87	8.96	0.96	4.63
3	1.67E-14	2.74E-06	1.63E-12	283	0.70	21.69	0.85	14.61
4	3.00E-01	4.11E-05	5.00E-02	194	0.91	8.31	0.96	7.37
5	1.74E-01	9.12E-06	0.00E+00	234	0.89	10.93	0.94	6.54
6	3.00E-01	1.00E-05	0.00E+00	138	0.93	6.87	0.93	5.85
7	0.00E+00	0.00E+00	0.00E+00	1000	0.99	5.01	0.99	6.49
8	0.00E+00	1.22E-06	5.00E-02	132	0.93	9.86	0.95	11.74
9	0.00E+00	0.00E+00	0.00E+00	158	0.79	14.43	0.86	16.75
10	0.00E+00	9.86E-06	3.21E-03	147	0.80	10.90	0.84	16.84
11	1.85E-01	4.13E-05	5.00E-02	129	0.96	3.65	0.99	2.45
12	5.00E-02	8.05E-06	2.49E-09	157	0.94	6.86	0.98	3.76
13	1.00E-01	7.94E-06	4.35E-03	100	0.96	6.41	0.85	11.78
14	0.00E+00	0.00E+00	5.00E-02	187	0.75	21.08	0.95	13.87
15	5.36E-02	9.85E-06	3.74E-02	170	0.97	6.84	0.95	9.60
16	1.90E-01	0.00E+00	5.00E-02	134	0.90	13.39	0.96	13.06
17	3.00E-01	1.00E-05	2.56E-02	89	0.88	7.46	0.97	6.03
18	1.34E-01	2.69E-05	5.00E-02	130	0.93	6.01	0.93	6.82
19	1.37E-02	0.00E+00	2.28E-03	47	0.94	2.96	0.97	5.10
20	3.00E-01	9.12E-06	3.57E-09	90	0.92	5.33	0.98	4.97
Means	1.28E-01	1.49E-05	1.94E-02	188	0.89	9.20	0.94	8.73

	Parameters				Trials 1-30		Trials 31-50	
Seller	*d*	w^+	w^-	*z*	R^2	*RMSE*	R^2	*RMSE*
21	0.00E+00	1.92E-03	5.00E-02	121	0.92	5.06	0.86	5.54
22	0.00E+00	4.32E-03	2.44E-02	80	0.88	4.36	0.70	9.25
23	0.00E+00	0.00E+00	5.00E-02	53	0.74	6.81	0.96	4.77
24	1.54E-01	3.39E-03	5.00E-02	124	0.70	8.11	0.79	10.15
25	0.00E+00	5.47E-03	2.26E-02	577	0.83	9.63	0.57	13.50
26	0.00E+00	6.84E-04	2.42E-02	49	0.56	9.99	0.77	10.96
27	0.00E+00	5.75E-04	0.00E+00	200	0.72	12.03	0.94	4.73
28	0.00E+00	0.00E+00	5.00E-02	119	0.89	6.69	0.93	5.19
29	7.30E-02	9.65E-03	0.00E+00	1484	0.42	16.68	0.03	22.61
30	0.00E+00	0.00E+00	5.00E-02	118	0.89	7.16	0.87	6.34
31	5.20E-02	0.00E+00	5.00E-02	223	0.95	5.32	1.00	2.12
32	1.28E-02	0.00E+00	6.25E-03	80	0.95	3.49	0.97	3.22
33	3.00E-01	3.92E-03	0.00E+00	352	0.98	3.76	0.98	3.68
34	3.08E-02	2.48E-03	5.00E-02	99	0.72	6.42	0.61	11.47
35	0.00E+00	7.73E-04	4.14E-03	48	0.86	4.27	0.88	7.06
36	1.94E-01	1.00E-03	5.00E-02	64	0.63	9.60	0.46	15.01
37	2.90E-02	2.84E-03	1.55E-02	31	0.85	4.66	0.66	14.32
38	1.20E-01	7.81E-03	0.00E+00	298	0.95	4.30	0.61	11.51
39	1.77E-02	4.90E-04	2.79E-02	48	0.93	3.80	0.94	6.61
40	3.00E-01	1.43E-04	0.00E+00	63	0.87	5.37	0.47	9.93
Means	6.42E-02	2.27E-03	2.62E-02	212	0.81	6.88	0.75	8.90

TABLE 6-2a. Learning Model Results, Partial Bonus Condition

	Parameters				Trials 1-30		Trials 31-50	
Buyer	d	w^+	w^-	y	R^2	*RMSE*	R^2	*RMSE*
1	1.70E-01	1.00E-04	0.00E+00	354	0.95	12.09	1.00	9.01
2	1.00E-02	0.00E+00	1.40E-03	71	0.96	3.87	0.98	3.04
3	2.00E-01	1.00E-04	5.00E-02	214	0.88	20.74	0.91	37.96
4	3.00E-01	1.00E-05	1.00E-03	68	0.98	2.22	0.97	3.18
5	1.00E-03	0.00E+00	8.75E-04	52	0.96	3.58	0.97	2.85
6	3.00E-01	0.00E+00	5.00E-02	57	0.96	7.84	1.00	10.00
7	0.00E+00	0.00E+00	5.00E-02	569	0.99	4.85	0.99	6.15
8	5.64E-02	0.00E+00	5.00E-02	500	0.97	8.08	0.98	7.90
9	0.00E+00	0.00E+00	1.39E-02	208	0.96	7.91	0.95	11.18
10	3.00E-01	1.00E-05	1.00E-03	88	0.87	6.57	0.83	7.23
11	1.23E-01	0.00E+00	5.00E-02	213	0.99	3.81	0.99	4.46
12	0.00E+00	0.00E+00	1.40E-03	190	0.97	6.55	0.99	3.92
13	1.90E-01	0.00E+00	3.00E-01	327	0.65	31.73	0.98	10.07
14	3.00E-01	1.70E-05	7.22E-09	119	0.98	3.26	0.97	4.48
15	3.00E-01	1.00E-06	5.00E-02	300	0.97	7.12	0.99	8.46
16	3.00E-01	0.00E+00	5.00E-02	89	0.86	8.16	0.74	8.32
17	3.00E-01	1.45E-05	1.89E-09	300	0.98	4.73	0.96	13.22
18	4.42E-02	0.00E+00	3.42E-03	41	0.98	2.03	0.91	6.47
19	1.98E-01	0.00E+00	2.75E-02	101	0.99	3.03	0.97	6.04
20	3.00E-01	0.00E+00	0.00E+00	132	0.86	10.81	0.94	6.98
Means	1.70E-01	1.26E-05	3.50E-02	200	0.94	7.95	0.95	8.55

	Parameters				Trials 1-30		Trials 31-50	
Seller	d	w^+	w^-	z	R^2	*RMSE*	R^2	*RMSE*
21	0.00E+00	9.42E-04	1.25E-02	100	0.99	1.88	0.96	3.94
22	0.00E+00	0.00E+00	5.00E-02	101	0.76	8.82	0.97	11.84
23	0.00E+00	2.46E-03	5.00E-02	166	0.66	9.90	0.73	9.59
24	0.00E+00	1.07E-03	5.00E-02	114	0.84	6.46	0.97	8.24
25	0.00E+00	0.00E+00	0.00E+00	325	0.95	5.53	0.97	5.56
26	8.62E-02	4.62E-03	3.67E-02	76	0.83	5.05	0.85	9.75
27	0.00E+00	4.03E-03	0.00E+00	99	0.42	11.64	0.33	21.17
28	1.10E-01	0.00E+00	1.43E-02	9	0.36	8.85	0.89	4.55
29	7.90E-02	3.62E-03	5.00E-02	188	0.52	12.80	0.31	16.42
30	3.00E-01	1.69E-03	5.00E-02	91	0.64	10.30	0.97	3.58
31	0.00E+00	0.00E+00	5.00E-02	77	0.67	10.18	0.63	14.42
32	2.99E-01	1.00E-01	4.03E-02	40	0.88	9.34	0.90	11.11
33	0.00E+00	0.00E+00	5.00E-02	15	0.49	11.51	0.84	10.13
34	0.00E+00	1.00E-03	8.27E-04	12	0.33	1.41	0.05	4.08
35	3.00E-01	5.00E-02	0.00E+00	150	0.91	8.23	0.99	6.85
36	3.00E-01	0.00E+00	2.76E-02	100	0.90	5.50	0.98	4.39
37	0.00E+00	9.44E-04	5.00E-02	27	0.91	5.18	0.85	9.63
38	7.64E-02	0.00E+00	5.00E-02	132	0.99	2.47	0.97	3.11
39	1.25E-01	0.00E+00	5.00E-02	98	0.91	5.24	0.94	5.81
40	8.20E-02	3.27E-04	5.00E-02	174	0.89	7.29	0.91	11.54
Means	8.79E-02	8.54E-03	3.41E-02	105	0.74	7.38	0.80	8.79

TABLE 6-2b. Learning model results, Full Bonus Condition

Buyer	Parameters: d	w^+	w^-	y	Trials 1-30: R^2	$RMSE$	Trials 31-50: R^2	$RMSE$
1	1.03E-01	2.55E-05	1.99E-02	190	0.96	5.05	0.87	14.58
2	8.00E-02	0.00E+00	5.00E-02	332	0.97	7.17	0.99	4.19
3	3.00E-01	1.07E-06	9.86E-03	55	0.94	3.55	0.89	4.52
4	3.00E-01	3.50E-05	2.28E-03	105	0.87	7.53	0.80	23.77
5	3.00E-01	9.50E-06	1.53E-03	184	0.88	11.04	0.74	14.16
6	1.00E-01	1.00E-05	5.00E-02	316	0.95	8.55	0.84	18.76
7	2.08E-01	6.32E-05	1.53E-02	98	0.95	3.62	0.96	4.82
8	1.51E-01	5.72E-05	5.00E-02	176	0.95	4.62	0.83	7.91
9	3.00E-01	4.07E-05	1.41E-11	79	0.96	2.64	0.96	3.00
10	3.00E-01	3.29E-05	4.12E-10	65	0.92	3.35	0.97	3.38
11	3.00E-01	5.91E-05	5.00E-02	129	0.94	4.28	0.96	4.18
12	2.50E-01	1.00E-04	5.00E-02	213	0.97	9.63	1.00	5.24
13	3.00E-01	1.00E-05	5.00E-02	79	0.91	6.74	0.91	6.60
14	3.00E-01	6.27E-05	5.00E-02	91	0.96	3.95	0.96	4.90
15	6.43E-11	9.59E-06	5.00E-02	202	0.91	12.40	0.89	13.44
16	1.00E-01	0.00E+00	5.00E-02	316	0.90	12.61	1.00	12.42
17	0.00E+00	0.00E+00	5.00E-02	68	0.96	6.14	0.98	8.89
18	3.00E-01	2.00E-04	0.00E+00	296	1.00	3.83	1.00	0.77
19	3.00E-01	5.74E-06	5.00E-02	52	0.96	2.40	0.95	2.74
20	3.00E-01	2.00E-04	0.00E+00	120	0.99	6.82	1.00	1.07
Means	2.15E-01	4.61E-05	2.99E-02	158	0.94	6.30	0.93	7.97

Seller	Parameters: d	w^+	w^-	z	Trials 1-30: R^2	$RMSE$	Trials 31-50: R^2	$RMSE$
21	6.44E-03	0.00E+00	3.63E-02	100	0.65	11.38	0.76	16.29
22	4.34E-02	0.00E+00	1.75E-02	120	0.95	4.26	0.99	3.45
23	1.16E-01	2.45E-03	5.00E-02	80	0.92	3.89	0.90	4.94
24	0.00E+00	0.00E+00	5.00E-02	13	0.72	6.84	0.67	16.50
25	0.00E+00	0.00E+00	5.00E-02	13	0.58	12.87	0.78	10.81
26	0.00E+00	2.13E-04	5.00E-02	73	0.96	3.68	0.91	7.34
27	2.17E-01	6.28E-03	5.00E-02	326	0.99	2.67	0.98	2.42
28	0.00E+00	0.00E+00	1.12E-03	90	0.27	15.25	0.80	9.04
29	5.11E-02	0.00E+00	3.88E-02	188	0.99	1.89	0.99	3.42
30	3.00E-01	9.98E-03	8.52E-03	85	0.24	9.57	0.84	4.18
31	1.78E-02	0.00E+00	5.00E-02	90	0.96	4.00	0.90	13.32
32	4.52E-02	0.00E+00	1.53E-02	120	0.98	2.86	0.99	2.97
33	0.00E+00	1.22E-03	5.00E-02	200	0.94	5.52	0.97	4.16
34	3.00E-01	5.04E-04	5.00E-02	100	0.94	3.47	0.96	7.55
35	2.93E-01	1.00E-02	2.23E-02	100	0.54	7.99	0.94	7.68
36	0.00E+00	1.00E-03	4.21E-02	30	0.26	7.95	0.46	11.38
37	3.00E-01	1.26E-03	5.00E-02	210	0.93	6.11	0.98	12.72
38	0.00E+00	0.00E+00	5.00E-02	60	0.71	8.48	0.93	7.16
39	1.99E-01	1.00E-02	4.25E-02	188	0.78	6.90	0.98	7.68
40	1.55E-01	5.45E-03	4.21E-02	30	0.73	3.56	0.54	3.28
Means	1.02E-01	2.42E-03	3.83E-02	111	0.75	6.46	0.86	7.81

TABLE 6-2c. Learning Model Results, Reframed Full Bonus Condition

	Parameters				Trials 1-30		Trials 31-50	
Buyer	d	w^+	w^-	y	R^2	*RMSE*	R^2	*RMSE*
1	0.00E+00	5.41E-06	5.00E-02	130	0.96	5.34	0.93	9.71
2	2.60E-01	1.00E-04	5.00E-02	320	0.86	21.81	0.97	11.74
3	6.85E-02	7.01E-06	5.00E-02	336	0.95	8.90	0.87	10.11
4	3.00E-01	8.25E-05	5.00E-02	108	0.91	4.67	0.87	6.59
5	1.20E-09	0.00E+00	5.00E-02	202	0.93	11.54	1.00	9.86
6	2.00E-01	0.00E+00	5.00E-02	242	0.96	7.71	0.98	7.46
7	0.00E+00	0.00E+00	5.00E-02	300	0.91	11.72	0.95	11.99
8	3.00E-01	0.00E+00	5.00E-02	345	1.00	2.74	0.99	4.92
9	3.00E-01	0.00E+00	0.00E+00	71	0.91	5.18	0.95	4.52
10	0.00E+00	0.00E+00	5.00E-02	113	0.94	11.91	0.59	34.85
11	3.00E-01	5.63E-05	5.00E-02	136	0.87	6.88	0.96	6.85
12	0.00E+00	0.00E+00	0.00E+00	1000	0.98	8.36	0.97	10.36
13	0.00E+00	0.00E+00	0.00E+00	1000	1.00	4.06	1.00	1.23
14	3.00E-01	6.07E-05	5.00E-02	299	0.89	8.43	0.84	11.92
15	6.82E-02	1.83E-06	5.00E-02	1000	1.00	2.32	0.99	3.50
16	0.00E+00	0.00E+00	5.00E-02	200	0.92	9.97	0.99	12.28
17	0.00E+00	0.00E+00	0.00E+00	500	0.99	4.88	0.99	4.70
18	3.00E-01	0.00E+00	5.00E-02	300	0.98	5.73	0.98	10.35
19	8.12E-02	1.05E-05	5.00E-02	78	0.84	15.59	0.97	9.34
20	3.00E-01	1.77E-05	5.00E-02	97	0.93	4.89	0.97	3.02
Means	1.39E-01	1.71E-05	4.00E-02	339	0.94	8.13	0.94	9.27

	Parameters				Trials 1-30		Trials 31-50	
Seller	d	w^+	w^-	z	R^2	*RMSE*	R^2	*RMSE*
21	2.00E-01	0.00E+00	5.00E-02	200	0.64	13.81	0.95	9.08
22	3.00E-01	0.00E+00	0.00E+00	220	0.97	3.63	1.00	1.82
23	0.00E+00	5.79E-03	7.69E-03	800	0.42	17.81	0.22	15.13
24	3.00E-01	0.00E+00	0.00E+00	200	0.96	3.79	0.93	12.18
25	4.00E-02	0.00E+00	5.00E-02	160	0.91	6.51	0.99	3.22
26	0.00E+00	0.00E+00	5.00E-02	189	0.92	5.77	0.99	6.21
27	1.48E-01	8.91E-04	5.00E-02	49	0.73	7.24	0.93	7.71
28	0.00E+00	0.00E+00	5.00E-02	400	0.95	5.66	1.00	2.55
29	1.07E-01	0.00E+00	5.00E-02	30	0.94	3.92	0.98	4.38
30	3.00E-01	0.00E+00	5.00E-02	120	0.78	9.27	0.28	15.37
31	1.04E-01	1.14E-03	5.00E-02	101	0.95	3.91	0.93	5.53
32	9.97E-02	1.81E-03	5.00E-02	24	0.37	6.19	0.26	7.51
33	0.00E+00	5.19E-03	0.00E+00	41	0.24	7.60	0.04	7.19
34	0.00E+00	0.00E+00	5.00E-02	12	0.83	6.80	0.96	11.95
35	0.00E+00	0.00E+00	0.00E+00	500	0.94	6.54	1.00	2.56
36	2.55E-01	0.00E+00	5.00E-02	100	0.80	8.46	1.00	9.75
37	3.00E-01	4.39E-03	1.66E-08	100	0.68	7.32	0.78	4.45
38	0.00E+00	0.00E+00	5.00E-02	500	0.95	5.75	1.00	1.60
39	3.00E-01	1.00E-02	0.00E+00	913	0.82	9.70	1.00	10.50
40	3.00E-01	7.17E-03	5.00E-02	994	0.74	13.08	0.14	34.89
Means	1.38E-01	1.82E-03	3.29E-02	283	0.78	7.64	0.77	8.68

TABLE 6-3a. Learning Model Results, Two-stage Inexperienced Condition

Buyer	*d*	*w*+	*w*-	*y*	No. of 2nd Stages	First 30 Stages 2 R^2	First 30 Stages 2 *RMSE*	Remaining Trials R^2	Remaining Trials *RMSE*
1	1.12E-10	9.09E-06	5.00E-02	231	42	0.68	16.78	0.94	9.27
2	0.00E+00	2.31E-06	6.23E-04	161	45	0.86	12.08	0.98	3.66
3	0.00E+00	2.37E-06	0.00E+00	272	49	0.96	7.37	0.91	20.88
4	3.00E-01	1.00E-05	3.48E-02	64	49	0.91	7.75	0.89	10.90
5	0.00E+00	1.27E-06	0.00E+00	613	46	0.98	6.65	0.91	11.20
6	0.00E+00	0.00E+00	0.00E+00	500	28	0.99	2.39	*	*
7	0.00E+00	0.00E+00	0.00E+00	550	46	0.96	7.95	0.96	14.16
8	0.00E+00	0.00E+00	0.00E+00	500	42	0.99	5.72	0.95	7.69
9	0.00E+00	2.43E-06	4.06E-12	130	46	0.93	7.83	0.76	11.18
10	0.00E+00	0.00E+00	0.00E+00	558	43	0.99	3.39	0.98	7.42
11	2.21E-09	5.67E-06	5.00E-02	220	50	0.90	8.73	0.85	13.41
12	5.53E-10	0.00E+00	6.01E-12	555	46	0.98	5.37	0.99	10.52
13	0.00E+00	3.60E-06	0.00E+00	161	42	0.99	3.47	0.87	8.15
14	0.00E+00	5.78E-06	0.00E+00	389	34	0.97	5.94	0.89	23.61
15	7.10E-11	2.21E-07	2.61E-11	872	42	0.98	4.67	0.87	15.61
16	0.00E+00	2.68E-06	0.00E+00	232	50	0.88	10.31	0.92	8.03
17	0.00E+00	0.00E+00	5.00E-02	95	41	0.84	11.30	0.75	28.22
18	0.00E+00	0.00E+00	5.00E-02	269	50	0.98	5.20	0.91	11.27
19	7.25E-11	5.59E-06	5.00E-02	433	46	0.97	7.33	0.94	7.45
20	0.00E+00	3.04E-06	6.74E-03	137	50	0.96	6.01	0.94	10.36
Means	1.50E-02	2.70E-06	1.46E-02	347	44	0.94	7.31	0.91	12.26

Seller	*d*	*w*+	*w*-	*z*	No. of 2nd Stages	First 30 Stages 2 R^2	First 30 Stages 2 *RMSE*	Remaining Trials R^2	Remaining Trials *RMSE*
1	2.52E-01	0.00E+00	5.00E-02	39	48	0.77	7.69	0.82	7.96
2	0.00E+00	0.00E+00	5.00E-02	38	46	0.70	15.50	0.68	15.89
3	0.00E+00	1.00E-04	5.00E-02	8	47	0.43	11.78	0.43	15.86
4	0.00E+00	2.10E-03	5.00E-02	13	44	0.67	10.60	0.34	10.84
5	1.07E-01	9.02E-03	0.00E+00	187	42	0.88	6.79	0.97	3.24
6	0.00E+00	4.81E-03	5.00E-02	170	36	0.80	9.19	0.76	12.45
7	0.00E+00	2.67E-03	5.00E-02	71	47	0.61	9.14	0.74	14.66
8	0.00E+00	4.28E-04	5.00E-02	18	48	0.82	9.33	0.96	3.94
9	3.61E-02	1.00E-02	7.35E-03	132	36	0.92	4.61	0.99	4.03
10	0.00E+00	0.00E+00	5.00E-02	27	42	0.94	4.73	0.94	5.40
11	0.00E+00	5.46E-04	0.00E+00	1429	43	0.89	7.96	0.65	17.70
12	0.00E+00	1.36E-03	1.60E-02	29	47	0.39	6.02	0.39	7.90
13	7.79E-02	0.00E+00	5.00E-02	60	50	0.28	12.66	0.74	10.52
14	1.77E-02	0.00E+00	5.00E-02	43	48	0.52	12.25	0.47	15.96
15	8.32E-03	6.17E-04	7.54E-04	82	41	0.75	7.83	0.85	5.02
16	0.00E+00	0.00E+00	5.00E-02	213	45	0.89	8.06	0.81	12.25
17	0.00E+00	0.00E+00	5.00E-02	15	47	0.55	13.91	0.65	12.13
18	6.38E-05	7.49E-04	5.00E-02	18	44	0.76	10.97	0.63	13.15
19	3.16E-02	0.00E+00	5.00E-02	22	47	0.89	6.10	0.64	14.11
20	0.00E+00	0.00E+00	0.00E+00	500	39	0.21	24.91	0.91	15.35
Means	2.65E-02	1.62E-03	3.62E-02	156	44	0.68	10.00	0.72	10.92

TABLE 6-3b. Learning model results, Two-stage Sophisticated Condition

Buyer	*d*	w^+	w^-	*y*	*No. of 2nd Stages*	*First 15 Stages 2* R^2	*RMSE*	*Remaining Trials* R^2	*RMSE*
21	0.00E+00	2.05E-05	4.78E-03	176	25	0.90	9.08	0.98	21.87
22	0.00E+00	3.87E-06	0.00E+00	137	25	0.93	6.21	0.94	10.69
23	0.00E+00	1.00E-05	9.84E-03	183	24	0.98	5.19	0.94	9.09
24	0.00E+00	3.23E-06	4.01E-04	149	25	0.96	4.90	0.99	9.29
25	0.00E+00	2.71E-06	0.00E+00	181	24	0.96	8.23	0.87	16.01
26	1.16E-10	8.01E-06	1.70E-09	55	24	0.97	1.79	0.97	7.10
27	0.00E+00	0.00E+00	4.31E-04	196	25	0.92	6.16	0.92	13.31
28	0.00E+00	1.45E-06	8.16E-10	167	25	0.96	6.27	0.91	9.56
29	0.00E+00	5.21E-07	0.00E+00	196	24	0.98	4.02	0.97	6.70
30	2.49E-06	1.52E-05	5.00E-02	159	24	0.98	3.91	0.83	6.52
Means	2.49E-07	5.00E-06	6.74E-03	158	24.5	0.96	5.19	0.93	9.81

Seller	*d*	w^+	w^-	*z*	*No. of 2nd Stages*	*First 15 Stages 2* R^2	*RMSE*	*Remaining Trials* R^2	*RMSE*
21	3.00E-01	6.12E-03	0.00E+00	56	25	0.86	4.29	0.91	6.30
22	0.00E+00	0.00E+00	4.59E-03	39	25	0.77	5.88	0.70	7.68
23	0.00E+00	0.00E+00	5.00E-02	57	25	0.83	6.60	0.58	11.40
24	0.00E+00	1.00E-04	4.15E-02	59	23	0.81	6.75	0.75	4.97
25	2.20E-01	0.00E+00	5.00E-02	279	25	0.98	3.09	0.99	3.49
26	3.00E-01	2.59E-03	0.00E+00	39	24	0.93	1.17	0.86	8.37
27	3.00E-01	6.28E-04	5.00E-02	200	24	0.19	21.31	#	#
28	0.00E+00	0.00E+00	0.00E+00	208	25	0.82	8.87	0.88	7.09
29	0.00E+00	1.50E-03	5.00E-02	72	25	0.92	4.23	0.93	6.24
30	1.00E-01	0.00E+00	2.00E-02	254	24	0.92	6.32	0.54	20.15
Means	1.22E-01	1.09E-03	2.66E-02	112.1	24.5	0.80	6.85	0.79	8.41

 # = Undefined as Seller 37 always asked 100 after Trial 12

gain and loss parameters, the common effect of $w^- > w^+$ was also observed with losses looming larger than gains. Three Experienced sellers (Sellers 33, 34, and 50) made more than twenty deals each during stage 1 preventing parameter tests on out-of-sample data. Seller 35 made one offer below her reservation value and three excessively strategic offers (above the LES), while most of the offers fell along the truth-telling line resulting in a very poor fit with R^2=0.20 and a RMSE=42.00. Seller 32 did well on in-sample estimation with R^2=0.89 but the out-of-sample test performed abysmally with R^2=0.04 due to a handful of

TABLE 6-3c. Learning Model Results, Two-stage Experienced Condition

Buyer	d	w^+	w^-	y	No. of 2nd Stages	First 30 Stages 2 R^2	First 30 Stages 2 RMSE	Remaining Trials R^2	Remaining Trials RMSE
31	0.00E+00	9.98E-06	5.00E-02	582	44	0.91	8.56	0.95	9.86
32	0.00E+00	0.00E+00	0.00E+00	500	37	0.94	9.00	0.99	5.03
33	0.00E+00	5.32E-06	3.49E-10	266	44	0.96	6.36	0.90	15.14
34	0.00E+00	4.67E-07	0.00E+00	2654	33	0.99	3.67	1.00	9.52
35	0.00E+00	1.25E-05	0.00E+00	674	22	0.46	27.77	*	*
36	2.28E-09	1.56E-07	5.00E-02	499	39	0.96	8.13	0.93	9.21
37	3.00E-01	0.00E+00	5.00E-02	178	35	0.90	10.57	0.97	6.39
38	0.00E+00	2.72E-06	0.00E+00	154	43	0.96	5.78	0.87	12.63
39	0.00E+00	1.67E-06	2.64E-10	134	46	0.93	7.38	0.84	8.53
40	5.42E-11	7.03E-06	5.00E-02	493	35	0.97	5.33	0.99	3.95
41	2.81E-01	5.06E-05	1.28E-02	164	43	0.99	3.30	0.99	3.51
42	8.23E-02	0.00E+00	2.50E-03	157	29	0.99	3.11	--	--
43	3.00E-01	2.92E-06	2.15E-09	150	41	0.98	4.60	0.92	9.10
44	3.00E-01	0.00E+00	5.00E-02	140	43	0.53	18.64	0.85	13.33
45	3.00E-01	1.00E-05	5.00E-02	317	41	0.95	8.82	0.96	4.25
46	1.00E-01	6.59E-08	0.00E+00	140	44	0.68	15.15	0.83	9.95
47	1.64E-01	1.00E-05	0.00E+00	169	36	0.90	8.23	0.97	5.86
48	3.00E-01	1.00E-05	8.25E-03	130	34	0.98	3.16	0.86	3.31
49	3.00E-01	1.00E-05	0.00E+00	146	49	0.76	12.47	0.84	13.43
50	3.00E-01	1.00E-05	2.00E-02	297	48	0.90	9.70	0.86	14.75
Means	1.36E-01	7.17E-06	1.72E-02	397	39	0.88	8.99	0.92	8.76

Seller	d	w^+	w^-	z	No. of 2nd Stages	First 30 Stages 2 R^2	First 30 Stages 2 RMSE	Remaining Trials R^2	Remaining Trials RMSE
31	1.53E-01	1.00E-02	0.00E+00	69	42	0.95	2.80	0.91	3.56
32	9.28E-02	8.89E-03	0.00E+00	124	33	0.89	4.33	0.04	11.06
33	2.14E-01	0.00E+00	5.00E-02	56	27	0.93	4.01	*	*
34	1.68E-01	1.00E-02	5.00E-02	30	28	0.96	3.62	*	*
35	0.00E+00	8.68E-04	5.00E-02	141	41	0.86	8.22	0.20	42.00
36	0.00E+00	0.00E+00	5.00E-02	159	45	0.91	7.47	0.96	9.01
37	2.37E-02	0.00E+00	5.00E-02	75	43	0.96	3.54	0.89	7.38
38	3.06E-02	5.17E-03	2.04E-02	201	43	0.90	4.80	0.82	4.72
39	7.23E-02	1.00E-02	0.00E+00	79	36	0.92	4.16	0.85	8.33
40	0.00E+00	1.41E-03	1.85E-02	28	40	0.73	4.89	0.23	11.78
41	2.40E-01	1.00E-02	3.20E-02	74	37	0.37	12.34	0.94	5.84
42	0.00E+00	7.51E-05	5.00E-02	87	50	0.77	9.67	0.70	15.71
43	5.26E-02	4.39E-03	5.00E-02	39	46	0.95	3.80	0.95	3.59
44	0.00E+00	1.42E-03	5.00E-02	120	45	0.84	7.05	0.91	5.82
45	8.00E-02	1.00E-02	2.32E-03	187	39	0.90	5.41	0.83	4.03
46	0.00E+00	0.00E+00	5.00E-02	120	44	0.86	7.51	0.96	14.22
47	0.00E+00	0.00E+00	1.50E-02	51	38	0.68	7.95	0.74	9.36
48	5.95E-02	0.00E+00	5.00E-02	25	50	0.94	5.31	0.91	6.15
49	3.37E-02	5.44E-03	2.31E-03	132	33	0.67	9.65	0.96	10.68
50	3.00E-01	9.68E-03	3.73E-02	29	26	0.89	3.96	*	*
Means	7.60E-02	4.37E-03	3.14E-02	91	39	0.84	6.02	0.75	10.19

low reservation offers deviating drastically from an otherwise stable strategy. Overall, the effects of sophistication and experience reduce variance in offer strategies yielding superior model fit in terms of both RMSE and R^2. The mean goodness of fit statistics are similar to those observed in single-stage games.

(5) Results: Extreme Information Asymmetry.

(a) Varying-k, Information-Advantaged.

(i) Buyer Model. Information-advantaged buyers in Conditions BB (Table 6-4a) and BS (Table 6-4b) showed some of the highest rates of learning with mean values of $0.189 < d \leq 0.20$. Sensitivity to losses, w^-, greatly exceeded the sensitivity to realized gains, w^+. Nearly twice the sensitivity to losses was observed when the buyer did not have power to affect the trade price. The estimated value of the free parameter, y, indicated the increased aggressiveness of buyers' bids in Condition BB (y=131) compared to Condition BS (y=246). The buyer model's fit was superior in Condition BS with R^2=0.97 both in and out-of-sample estimates. The performance was also good in Condition BB with R^2=0.86 estimated on the first thirty trials but decreased to R^2=0.72 on the last 20 trials. BB Buyers 1, 3, 8 and 9 demonstrated learning beyond trial 30 and largely contributed to the decreased model fit on the out-of-sample test. Nevertheless, the fit was quite good with very low RMSE--all below 8.14.

(ii) Seller Model. The seller model did much worse in accounting for the dynamics of the information-advantaged sellers in Condition SS (Table 6-4c) but did well in Condition SB (Table 6-4d). The mean R^2 and RMSE values for the partial data sample used to estimate the best-fitting parameters were $\overline{R^2}$ =0.37 and $\overline{\text{RMSE}}$ =90.16 in Condition SS

TABLE 6-4a. Varying-*k* learning model results, Dominating Player Treatment, Condition BB

	Parameters				Trials 1-30		Trials 31-50	
Buyers	d	w^+	w^-	y	R^2	*RMSE*	R^2	*RMSE*
BB Buyer 1	0.00E+00	2.47E-06	5.00E-02	140	0.94	5.99	0.65	48.67
BB Buyer 2	3.00E-01	9.25E-06	5.00E-02	399	0.97	6.46	0.98	8.50
BB Buyer 3	3.00E-01	2.40E-05	5.00E-02	72	0.94	4.94	0.73	9.88
BB Buyer 4	3.00E-01	1.00E-05	1.58E-02	19	0.82	2.10	0.81	3.31
BB Buyer 5	3.00E-01	1.31E-05	0.00E+00	142	0.91	7.71	0.93	6.11
BB Buyer 6	4.44E-10	1.00E-05	5.49E-09	60	0.65	7.41	0.63	8.52
BB Buyer 7	1.43E-09	7.56E-06	8.06E-08	143	0.89	6.46	0.78	7.32
BB Buyer 8	0.00E+00	7.44E-06	1.77E-14	131	0.88	7.02	0.72	8.80
BB Buyer 9	3.00E-01	3.38E-05	5.00E-02	111	0.86	6.06	0.46	17.09
BB Buyer 10	3.00E-01	6.26E-05	3.68E-02	100	0.83	4.77	0.79	3.75
Means	2.00E-01	1.97E-05	2.25E-02	131	0.86	5.88	0.76	8.14

	Parameters				Trials 1-30		Trials 31-50	
Sellers	d	w^+	w^-	z	R^2	*RMSE*	R^2	*RMSE*
BB Seller 1	6.37E-02	1.00E-02	5.00E-02	54	0.46	2.28	0.18	1.88
BB Seller 2	0.00E+00	0.00E+00	5.00E-02	101	0.05	5.33	0.99	4.82
BB Seller 3	1.40E-01	1.00E-02	5.00E-02	93	0.07	2.95	0.14	2.89
BB Seller 4	0.00E+00	0.00E+00	5.00E-02	114	0.13	5.09	0.20	5.10
BB Seller 5	0.00E+00	0.00E+00	5.00E-02	26	0.76	1.97	0.90	2.17
BB Seller 6	0.00E+00	1.69E-03	0.00E+00	1	0.11	0.23	0.02	0.44
BB Seller 7	0.00E+00	5.00E-03	2.69E-02	100	0.27	3.12	0.11	1.84
BB Seller 8	0.00E+00	0.00E+00	0.00E+00	50	0.00	4.47	1.00	6.10
BB Seller 9	1.24E-01	1.00E-02	0.00E+00	36	0.22	2.08	0.18	1.65
BB Seller 10	0.00E+00	1.00E-04	0.00E+00	100	0.00	5.45	1.00	5.45
Means	2.93E-02	2.98E-03	2.52E-02	69	0.18	3.41	0.50	3.38

and $\overline{R^2}$ =0.67 and $\overline{RMSE}$ =92.58 in Condition SB. Although the out-of-sample results improved (R^2=0.55 in Condition SS and R^2=0.90 in Condition SB), the results are questionable. It is suspected that the manner in which subjects were recruited for these

TABLE 6-4b. Varying-*k* learning model results, Balanced Power Treatment, Condition BS

	Parameters				Trials 1-30		Trials 31-50	
Buyers	*d*	*w*+	*w*−	*y*	R^2	*RMSE*	R^2	*RMSE*
BS Buyer 1	0.00E+00	0.00E+00	3.00E-02	253	0.98	6.07	0.99	11.19
BS Buyer 2	3.00E-01	0.00E+00	5.00E-02	421	0.96	9.66	0.91	13.76
BS Buyer 3	3.00E-01	0.00E+00	5.00E-02	232	0.93	12.14	1.00	3.17
BS Buyer 4	3.00E-01	1.78E-05	5.00E-02	145	0.95	7.23	0.97	11.16
BS Buyer 5	3.00E-01	0.00E+00	5.00E-02	253	0.99	4.84	0.98	5.03
BS Buyer 6	0.00E+00	0.00E+00	5.00E-02	176	0.97	6.36	0.99	6.29
BS Buyer 7	0.00E+00	5.03E-07	5.00E-02	262	0.99	3.33	0.99	5.46
BS Buyer 8	3.00E-01	0.00E+00	3.00E-02	152	0.97	5.04	0.97	5.47
BS Buyer 9	2.00E-01	0.00E+00	5.00E-02	156	0.97	5.29	0.96	6.88
BS Buyer 10	0.00E+00	0.00E+00	5.00E-02	421	0.98	6.18	0.99	5.98
Means	1.89E-01	2.04E-06	4.78E-02	246	0.97	6.68	0.97	7.02

	Parameters				Trials 1-30		Trials 31-50	
Sellers	*d*	*w*+	*w*−	z	R^2	*RMSE*	R^2	*RMSE*
BS Seller 1	3.15E-02	0.00E+00	5.00E-02	10	0.00	2.60	0.01	2.61
BS Seller 2	0.00E+00	0.00E+00	5.00E-02	101	0.00	5.45	0.06	5.64
BS Seller 3	7.00E-03	5.72E-03	5.00E-02	23	0.36	2.01	0.02	2.84
BS Seller 4	0.00E+00	1.00E-03	5.00E-02	114	0.07	4.47	0.00	4.08
BS Seller 5	0.00E+00	1.00E-03	0.00E+00	87	0.31	3.77	0.18	5.08
BS Seller 6	8.62E-02	4.62E-03	3.67E-02	76	0.08	3.00	0.29	4.60
BS Seller 7	0.00E+00	1.00E-03	0.00E+00	43	0.21	3.47	0.39	3.54
BS Seller 8	1.68E-02	1.00E-03	0.00E+00	9	0.13	1.76	0.00	2.65
BS Seller 9	0.00E+00	9.15E-04	5.00E-02	14	0.20	2.19	0.02	3.47
BS Seller 10	0.00E+00	0.00E+00	5.00E-02	23	0.18	3.81	0.25	4.09
Means	1.22E-02	1.70E-03	3.19E-02	54	0.17	3.33	0.13	4.00

conditions had an adverse impact. As noted in Chapter V, subjects in Condition SS consisted of undergraduate students midway through a bargaining class having already participated in several laboratory bargaining experiments, all of which employed a midpoint trading rule with $k = 1/2$. Subjects in Condition SB were sophisticated players (economics

TABLE 6-4c. Varying-*k* learning model results, Dominating Player Treatment, Condition SS

	Parameters				Trials 1-30		Trials 31-50	
Buyers	*d*	*w*+	*w*−	*y*	R^2	*RMSE*	R^2	*RMSE*
SS Buyer 1	0.00E+00	0.00E+00	5.00E-02	100	0.87	7.94	*	*
SS Buyer 2	1.00E-02	0.00E+00	1.40E-03	71	0.68	0.88	0.01	0.51
SS Buyer 3	0.00E+00	0.00E+00	5.00E-02	50	0.17	40.59	0.19	46.93
SS Buyer 4	0.00E+00	0.00E+00	5.00E-02	50	0.82	12.55	0.23	6.37
SS Buyer 5	3.00E-01	2.94E-04	5.00E-02	23	0.48	8.03	0.78	7.64
SS Buyer 6	4.16E-10	2.50E-06	1.11E-02	85	0.60	16.33	0.06	5.94
SS Buyer 7	3.00E-01	0.00E+00	5.00E-02	50	0.59	0.09	0.75	0.08
SS Buyer 8	2.00E-01	1.00E-05	4.92E-02	174	0.11	16.16	0.14	12.98
SS Buyer 9	3.00E-01	0.00E+00	5.00E-02	214	0.93	1.56	1.00	0.13
SS Buyer 10	0.00E+00	0.00E+00	0.00E+00	34	0.99	0.00	1.00	0.00
Means	1.23E-01	3.41E-05	3.46E-02	84	0.60	10.69	0.46	8.95

	Parameters				Trials 1-30		Trials 31-50	
Sellers	*d*	*w*+	*w*−	*z*	R^2	*RMSE*	R^2	*RMSE*
SS Seller 1	2.27E-01	1.61E-03	1.36E-02	40	0.95	74.85	0.44	267.94
SS Seller 2	2.23E-01	1.00E-05	0.00E+00	128	0.22	107.87	0.46	80.48
SS Seller 3	3.00E-01	5.52E-03	3.99E-02	243	0.37	65.77	0.62	73.12
SS Seller 4	0.00E+00	0.00E+00	5.00E-02	266	0.41	49.59	0.59	49.87
SS Seller 5	3.01E-02	0.00E+00	5.00E-02	44	0.43	76.05	0.45	92.70
SS Seller 6	0.00E+00	0.00E+00	3.09E-02	119	0.16	68.93	0.31	49.74
SS Seller 7	3.00E-01	0.00E+00	1.40E-02	46	0.71	145.94	0.85	137.37
SS Seller 8	2.66E-01	0.00E+00	5.00E-02	40	0.13	66.08	0.53	65.90
SS Seller 9	0.00E+00	0.00E+00	5.00E-02	128	0.70	41.47	0.54	55.59
SS Seller 10	3.00E-01	1.00E-03	2.80E-02	39	0.24	189.77	0.59	167.06
Means	1.58E-01	7.26E-04	3.48E-02	117	0.37	90.16	0.55	85.76

graduate students) involved in a summer workshop sponsored by the Economics Science Laboratory. The results of Condition SB Sellers are relatively consistent with the isomorphic players (buyers in Condition BS) with the principal exception being the RMSE of the out-of-sample fit (102.88 compared to 7.02), while the R^2 values are within 0.07. Three of the ten

TABLE 6-4d. Varying-*k* learning model results, Balanced Power Treatment, Condition SB

	Parameters				Trials 1-30		Trials 31-50	
Buyers	d	w^{+}	w^{-}	y	R^2	RMSE	R^2	RMSE
SB Buyer 1	0.00E+00	9.90E-08	1.32E-05	28	0.38	0.01	0.23	0.02
SB Buyer 2	0.00E+00	1.82E-07	4.81E-05	22	0.17	0.03	0.29	0.06
SB Buyer 3	0.00E+00	1.00E-05	2.00E-02	49	0.35	18.84	0.02	24.84
SB Buyer 4	0.00E+00	0.00E+00	5.00E-02	89	0.07	32.07	0.19	22.82
SB Buyer 5	1.00E-03	0.00E+00	8.75E-04	52	0.00	4.90	0.12	15.17
SB Buyer 6	3.00E-01	0.00E+00	5.00E-02	57	0.14	10.50	0.03	2.94
SB Buyer 7	1.79E-07	1.14E-06	2.04E-04	142	0.42	2.18	0.45	5.58
SB Buyer 8	0.00E+00	1.14E-06	2.04E-04	83	0.32	2.23	0.05	6.24
SB Buyer 9	8.04E-02	0.00E+00	5.00E-02	477	0.40	6.46	0.16	16.95
SB Buyer 10	3.00E-01	1.00E-05	1.00E-03	88	0.01	1.11	0.03	0.57
Means	7.57E-02	2.50E-06	1.91E-02	118	0.21	8.70	0.15	10.57

	Parameters				Trials 1-30		Trials 31-50	
Sellers	d	w^{+}	w^{-}	z	R^2	RMSE	R^2	RMSE
SB Seller 1	3.00E-01	0.00E+00	1.08E-02	53	0.85	76.22	0.85	186.65
SB Seller 2	0.00E+00	0.00E+00	5.00E-02	267	0.85	26.35	0.85	29.76
SB Seller 3	0.00E+00	0.00E+00	5.00E-02	111	0.26	56.81	0.87	40.97
SB Seller 4	0.00E+00	1.07E-03	5.00E-02	114	0.92	33.63	0.83	57.80
SB Seller 5	6.40E-02	4.89E-03	1.44E-02	82	0.94	36.09	0.89	84.52
SB Seller 6	3.00E-01	0.00E+00	5.00E-02	43	0.45	405.35	0.86	338.83
SB Seller 7	0.00E+00	0.00E+00	5.00E-02	99	0.57	56.15	1.00	75.77
SB Seller 8	0.00E+00	1.00E-04	0.00E+00	82	0.19	154.29	0.89	240.61
SB Seller 9	3.00E-01	2.51E-03	5.00E-02	129	0.99	9.50	0.98	10.66
SB Seller 10	0.00E+00	1.45E-04	1.23E-02	75	0.87	55.02	0.92	47.02
Means	7.38E-02	9.68E-04	3.63E-02	111	0.67	92.58	0.90	102.88

SB Sellers exhibited RMSE in excess of 180, more that 100 more than the next closest seller. Eliminating these three sellers would retain the same model fit (R^2 increasing by only 0.01) but reduce the RMSE by 60%.

(b) Varying-*k*, Information-Disadvantaged.

(i) Buyer Model. Performance of the model for information-disadvantaged buyers in Conditions SS and SB was exceptionally poor. Although the R^2 for Condition SS buyers was R^2=0.60 in-sample, it declined to R^2=0.46 out-of-sample supported only by two truth-telling players (SS Buyers 9 and 10) with respective RMSE=0.13 and RMSE=0.00. By excluding the performance of these two subjects, the overall model fit degraded to R^2=0.31 and RMSE=11.5. The preponderance of information-disadvantaged buyer behavior in the face of an extreme information asymmetry indicates that offers are largely independent of reservation values limiting the ability of the DSR learning model to accurately capture learning effects.

(ii) Seller Model. For reasons stated above, performance of the information-disadvantaged sellers in Conditions BB and BS was similarly poor. The seller model fared the worst in Condition BS yielding R^2 values of R^2=0.17 and R^2=0.13. In Condition BB, R^2=0.18 but improved to R^2=0.50 on the out-of-sample data. However, as previously noted, this improvement was largely an artifact of truth-telling behavior throughout the experiment by a relatively few players. Overall, the seller model did equally poorly in the case of extreme information asymmetry biased against the seller.

(6) Learning Model Discussion. The DSR learning model does a remarkable job of accounting for individual learning of players in the vast majority of cases under conditions of moderate information asymmetry. Table 6-5 summarizes mean parameter values for all experiments in Chapters II through V and Figure 6-1 illustrates the comparison separately each parameter. Learning was most pronounced for the information-advantaged buyers in

TABLE 6-5. Learning model summary results

BUYERS	Parameters				Trials 1-30*		Trials 31-50	
	d	w^+	w^-	y	Mean R^2	Mean RMSE	Mean R^2	Mean RMSE
DSR Experiment 1	6.05E-02	2.00E-03	4.12E-02	345	0.89	15.29	0.93	12.63
Baseline	1.28E-01	1.49E-05	1.94E-02	188	0.89	9.20	0.94	8.73
Bonus								
Partial	1.70E-01	1.26E-05	3.50E-02	200	0.94	7.95	0.95	8.55
Full	2.15E-01	4.61E-05	2.99E-02	158	0.94	6.30	0.93	7.97
Reframed Full	1.39E-01	1.71E-05	4.00E-02	339	0.94	8.13	0.94	9.27
Two-Stage								
Inexperienced	1.50E-02	2.70E-06	1.46E-02	347	0.94	7.31	0.91	12.26
Sophisticated	2.49E-07	5.00E-06	6.74E-03	158	0.96	5.19	0.93	9.81
Experienced	1.36E-01	7.17E-06	1.72E-02	397	0.88	8.99	0.92	8.76
Varying-*k*								
Condition BB	2.00E-01	1.97E-05	2.25E-02	131	0.86	5.88	0.76	8.14
Condition SS	1.23E-01	3.41E-05	3.46E-02	84	0.60	10.69	0.46	8.95
Condition BS	1.89E-01	2.04E-06	4.78E-02	246	0.97	6.68	0.97	7.02
Condition SB	7.57E-02	2.50E-06	1.91E-02	118	0.21	8.70	0.15	10.57

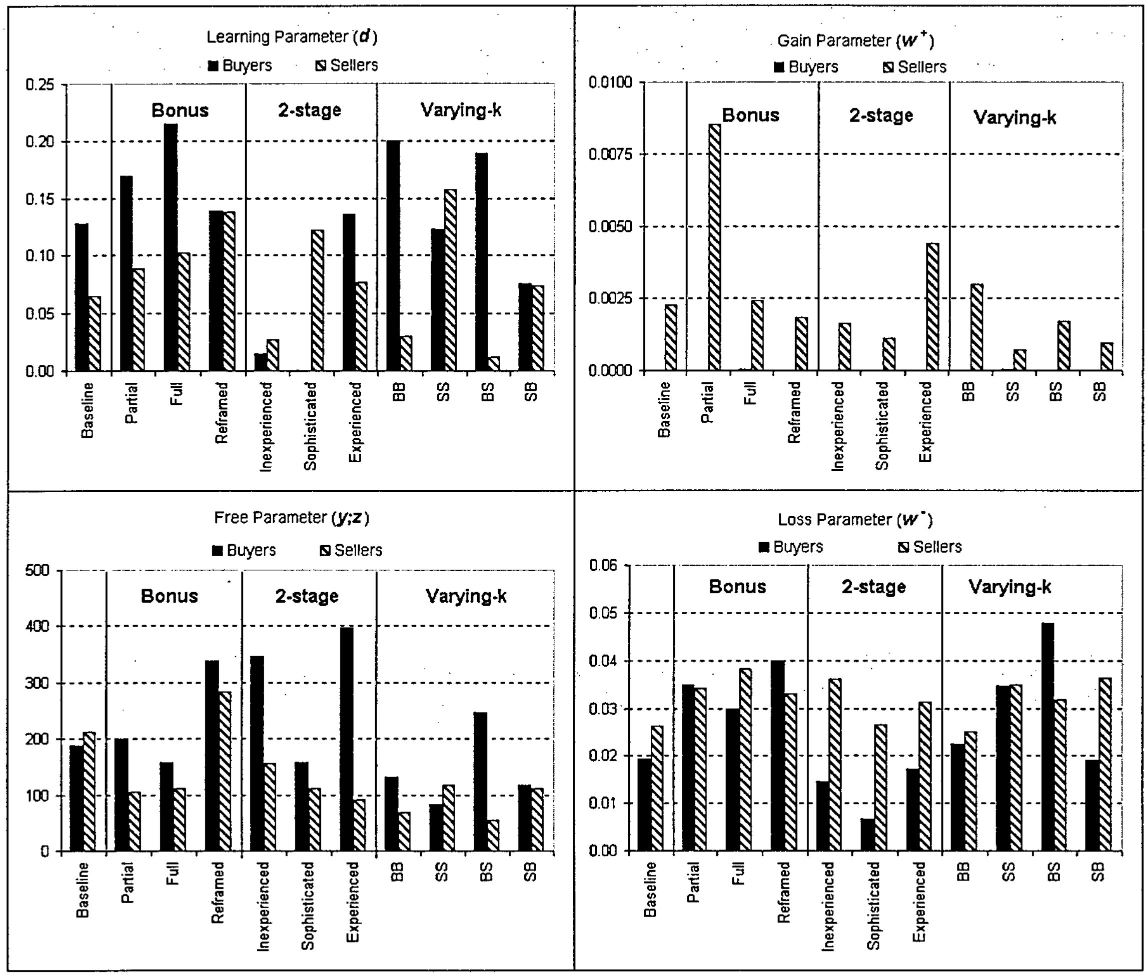
SELLERS	Parameters				Trials 1-30*		Trials 31-50	
	d	w^+	w^-	y	Mean R^2	Mean RMSE	Mean R^2	Mean RMSE
DSR Experiment 1	1.69E-01	3.80E-03	2.50E-02	208	0.90	9.31	0.82	8.73
Baseline	6.42E-02	2.27E-03	2.62E-02	212	0.81	6.88	0.75	8.90
Bonus								
Partial	8.79E-02	8.54E-03	3.41E-02	105	0.74	7.38	0.80	8.79
Full	1.02E-01	2.42E-03	3.83E-02	111	0.75	6.46	0.86	7.81
Reframed Full	1.38E-01	1.82E-03	3.29E-02	283	0.78	7.64	0.77	8.68
Two-Stage								
Inexperienced	2.65E-02	1.62E-03	3.62E-02	156	0.68	10.00	0.72	10.92
Sophisticated	1.22E-01	1.09E-03	2.66E-02	112	0.80	6.85	0.79	8.41
Experienced	7.60E-02	4.37E-03	3.14E-02	91	0.84	6.02	0.80	10.14
Varying-*k*								
Condition BB	2.93E-02	2.98E-03	2.52E-02	69	0.18	3.41	0.50	3.38
Condition SS	1.58E-01	7.26E-04	3.48E-02	117	0.37	90.16	0.55	85.76
Condition BS	1.22E-02	1.70E-03	3.19E-02	54	0.17	3.33	0.13	4.00
Condition SB	7.38E-02	9.68E-04	3.63E-02	111	0.67	92.58	0.90	102.88

*First 15 trials for the Sophisticated condition

the Baseline condition. This pattern was also evident in the Bonus mechanism with learning increasing monotonically with the bonus implementation. Reframing the bonus appeared to have an effect of "clueing the buyers in" resulting in a decreased *d*, which in turn fostered a richer environment for adaptive learning of the sellers. Theoretically, the two-stage mechanism should not differ from the single-stage game since no learning would occur if players bilaterally revealed no information during stage 1. However, only the Experienced players demonstrated learning levels consistent with that of the single-stage Baseline game. Information revealing behavior by the Experienced sellers provided an opportunity for buyers to adapt their behavior to capitalize on the dominated strategies employed by the sellers. Over time, sellers in turn responded to buyers with the information revealing behavior diminishing and altogether disappearing by the end of the session. Sophisticated buyers were consistently aggressive demonstrating the smallest rates of learning over half the number of trials as the other groups effectively forcing the Sophisticated sellers to concede a larger portion of the surplus. Interestingly enough, the Inexperienced two-stage players exhibited some of the lowest rates of learning during stage 2 indicating that stage 2 offers remained relatively proportional to reservation values for each subject.

The top-right panel of Figure 6-1 illustrates the levels of the gain parameter, w^+, across experiments for sellers only since buyer levels were too small to be captured on the graph. Figure 6-2 shows relative levels of w^+ for the buyers separated on a rescaled graph. Although sellers were far more sensitive to gains than buyers across experiments, comparing the scales of the w^+ graphs to the scale of the loss parameter plot in the lower-right panel clearly shows the greater sensitivity to losses than gains in the reinforcement-based model.

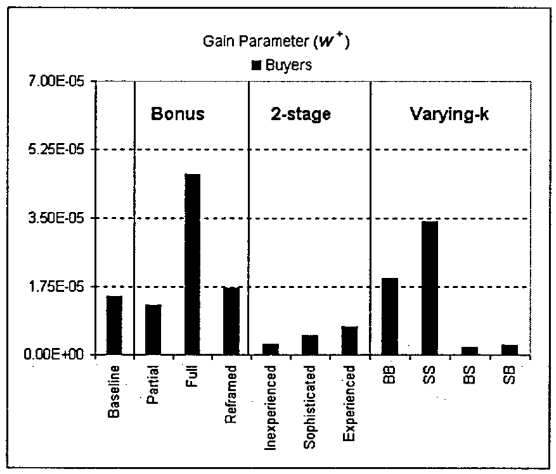
FIGURE 6-1. Learning Parameter Results Across Experiments



Finally, in the lower-left panel, comparisons of the values of the free parameters show that information-advantaged players (buyers in all cases except Conditions SS and SB in the Varying-*k* studies) are more aggressive than information-disadvantaged players except for the Baseline game, which yielded similar values. DSR Experiment 2 (1998) and SDR Experiment 2 (2001) each implemented an extreme information advantage alternatively favoring the buyers (F~uniform[0,20], G~uniform[0,200]) and sellers (F~uniform[0,200], G~uniform[180,200]). Results from DSR Experiment 1, which gave the information

advantage to the buyers, produced an estimated mean R^2 for buyers of $\overline{R^2}$ =0.90 in-sample and $\overline{R^2}$ =0.82 out of sample and for sellers, $\overline{R^2}$ =0.19 and $\overline{R^2}$ =0.48. SDR Experiment 2 which gave the information advantage to the seller produced similar isomorphic results with

FIGURE 6-2. Gain Parameter (w^+) Results



sellers generating an estimated mean R^2=0.84. SDR did not report a value for the buyer model but summarily dismissed it as being a very poor fit. Because of the conflicting results of information-advantaged players interchanging only player roles potentially induced by using experienced students, further study is necessary focusing specifically on Conditions SS and SB using standard subjects required to evaluate effects on seller model. Under conditions of information asymmetry, the learning model for the information-disadvantaged player consistently under-performed that of the information-advantaged player's model. With a smaller range of reservation values, finding a best fitting curve to explain the observed data reasonably well becomes more of a challenge for information-disadvantaged players.

CHAPTER VII: CONCLUSION

Despite the multiplicity of equilibria for two-person bargaining games of incomplete information, the Chatterjee-Samuelson linear equilibrium (LES) has emerged as both the theoretical and experimental static model of choice in the literature. Although Nash equilibrium concepts for this class of games are insufficient to describe and predict individual behavior in iterated play of the stage game, the LES has proven to be an effective first-order approximation whose performance is attenuated by information disparity. The DSR reinforcement-based adaptive learning model does exceptionally well in dynamically accounting for the trial-to-trial changes in the face of information asymmetry yielding accurate and robust predictions across the studies presented in this manuscript.

A. BONUS. Incorporation of a 'bonus player' into the two-person bargaining game under incomplete information induces significant differences from previously studied "no bonus" games. However, under a condition of asymmetric information, observed behavior in the Full Bonus condition fails to support the theoretical prediction of convergence to truthful revelation strategies. The propensity to bid strategically is robust and persists not only when it is a dominated strategy, but also when players are explicitly informed that strategic bidding cannot improve earnings. Information asymmetry in the Full Bonus condition yields no advantage to the buyers. However, the buyers resist improving seller earnings unilaterally by bidding truthfully beyond the sellers' upper distribution limit. Thus, buyers engage in strategic bidding even when doing so is of no consequence to their own performance. Reframing the Full Bonus condition by simplifying the payoff function and explicitly informing players that individual offers have no effect of earnings significantly

improves both efficiency and aggregate earnings, but not to the predicted levels. Trial-to-trial learning is well accounted for by the DSR reinforcement-based adaptive learning model for both buyers and sellers. In the face of considerable individual behavioral differences, the dynamic models for both the buyers and sellers are equally robust in capturing trial-to-trial variability in both non-bonus and bonus implemented institutions.

An obvious question raised by this study is to what level must the endogenous bonus be increased before dominant truthful revelation overcomes dominated strategic bidding. Additionally, to what extent does information asymmetry assail the dominant strategy in the Full Bonus condition? Further investigation of subsidy effects is warranted before drawing any general conclusions about a potential "hard wired" property of strategic bidding inherent in human decision processes.

B. TWO-STAGE. The results of the two-stage experiments clearly demonstrate that observed behavior is consistent with theoretical predictions: most often players reveal no useful information during stage 1 play relegating the game to a single-stage game by making serious offers during stage 2 only. Although all players begin by making information revealing offers during stage 1, the behavior dissipates with experience. Sophisticated players recognized the negative effects of stage 1 revelation almost immediately. All two-stage experiments produced more efficient outcomes than the Baseline Condition, but the improvements were small. As in previous single-stage experiments with an information disparity, both Experienced and Sophisticated buyers in the two-stage mechanism used their information-advantage to "push the sellers down" but to a much greater extent than previously noted. Two-stage Inexperienced buyers demonstrated similar performance although the information disparity effect was not as

pronounced and nearly identical to that observed in single-stage game. The DSR learning model effectively accounted for the dynamics of stage 2 play and captured the effect of players using stage 1 offers effectively to formulate their stage 2 offers, given that the stage 1 offer exceeded (is less than) the seller's (buyer's) reservation value indicating the certainty of a feasible trade.

The two-stage mechanism as proposed poses several concerns for future consideration. First, with no discounting between stages, players faced no risk of loss by making non-serious offers during stage 1 play since it was common knowledge that stage 2 would occur with certainty. Future experimentation should focus on incorporating a discount parameter as theorized by Stein (2001) between stages to induce an incentive of making a serious offer during stage 1. Second, under the present design, because an offer during stage 1 could consummate a deal, players were faced with the risk of revealing "too much" information and making a deal with a less-than-favorable trade price. Future studies of this mechanism also necessitate modification of stage 1 rules to allow for non-binding "signaling" offers providing a venue for revealing information and improving efficiency to ascertain the effects of cheap talk on the Bayesian-updating of the equilibrium at stage 2.

C. VARYING-*k*. Finally, the effects of varying-*k* have shown that the Information Disparity Hypothesis, which had been proposed by RDS under conditions where a midpoint trading rule was employed ($k = 1/2$), fails to yield an advantage beyond LES predictions if accompanied with price-setting power. In the Balanced Power treatment where one player was given exclusive price setting power and the other an extreme information advantage, the LES predicts that the price-setting empowered player should claim the majority of the surplus for

himself. Regardless of player roles, having an information advantage overcomes the disadvantage faced when a player only has veto-power over the trade price affording the information advantaged players a larger-than-predicted portion of the surplus. However, when a player is empowered with both price-setting power as well as an information advantage as in the Dominating Player treatment, a "judo effect" is observed where the weak player effectively uses the dominating player's power against himself forcing him to yield greater concessions to the weaker player than predicted by the LES. Efficiency in the Dominating Player treatment falls well below the equilibrium predictions but very near predictions in the Balanced Power treatment. Comparing observed data to simulation results indicates that in both treatments, although particularly so in the Dominating Player treatment, the price-setting player tends to set trade prices consistent with what would be expected if a midpoint trading rule had been employed. It is as if the price setting players recognize a "standard of fairness" and use it as a heuristic in formulating offers which deviate systematically from LES predictions. The dynamics of play for the information disadvantaged players are poorly captured by the learning model for the obvious reason that the range of reservation values is sufficiently small as to have little effect over the player's offer in the face of an extreme information disparity. With regards to the information-advantaged players, the learning model performs consistently well in all but one of the conditions where very little learning was evident.

Because many of the real-world applications of the sealed-bid mechanism employ extreme *k* institutions (namely, contracting within the federal government), further experimental study is warranted to isolate the critical point between the level of information disparity and the price setting power of a player where the extreme advantage induces negative implications.

Also, because of the differences in the subject populations used (experienced, sophisticated, and inexperienced players), replication of each condition is necessary to ensure the effects observed are not population specific, as noted in the two-stage study.

Furthering our understanding of bargaining is necessary to build the theoretical foundations of market behavior. But developing an understanding of markets requires at its base a theory of individual behavior in strategic situations. Individual differences constitute the greatest unresolved phenomenon of social science, and this noble pursuit necessitates an on-going collective effort between theoretical development and experimentation to extend our understanding of human behavior in strategic situations.

APPENDIX A. SUMMARY OF EXPERIMENTATION

Bilateral Bargaining Games Under Incomplete Information (Sealed-Bid *k*-Double Auction)

Study	*k*	Priors	Pairing	Trials	Payment	Key Findings
Radner and Schotter *JET 1989*	½ *	*F*~[0,100] *G*~[0,100]	Fixed	15	Cumulative	Observed behavior followed linear strategies
Rapoport and Fuller *JMP 1995*	½	*F*~[0,100] *G*~[0,100]	Random	25	Three random trials	LES and Truthful Revelation Model supported with symmetric supports; asymmetric supports yielded quasi-step functions and strategic behavior
	½	*F*~[0,100] *G*~[0,200]	Random	25	Three random trails	
Daniel, Seale and Rapoport *JMP 1998*	½	*F*~[0,100] *G*~[0,200]	Random	50	Cumulative	Information-advantaged players able to garner a larger share of gains from trade than predicted by LES; players more sensitive to losses than gains in adaptive learning
	½	*F*~[0,20] *G*~[0,200]	Random	50	Cumulative	
Rapoport, Daniel and Seale *EE 1998*	½	*F*~[0,100] *G*~[0,200]	Fixed	50	Cumulative	More support for information disparity hypothesis; effect magnified with fixed partners; learning model accounts for large percentage of variation
	½	*F*~[0,200] *G*~[100,200]	Fixed	50	Cumulative	
Seale, Daniel and Rapoport *JEBO 2001*	½	*F*~[0,200] *G*~[100,200]	Random	50	Cumulative	Exaggerated strategic bidding robust in the face of an information disparity independent of player role (buyer or seller); disadvantaged robots overcome disparity by bidding more aggressively.
	½	*F*~[0,200] *G*~[180,200]	Random	50	Cumulative	
	½	*F*~[0,100] *G*~[0,200]	Robot Sellers	50	Cumulative	

JET- Jour. of Econ. Theory; *JMP* - Jour. of Math. Psych.; *EE* - Exper. Econ.; *JEBO* - Journ. of Econ. Behav. and Org.

* Note: Of the eight experiments conducted, only three were discussed in detail (Experiments 1, 2, and 5). Experiment 4 (which was only briefly mentioned but not discussed in any level of detail) set k=1.

APPENDIX B. INSTRUCTIONS, BASELINE CONDITION

This study investigates bargaining between a buyer and seller. If you make good decisions, you may earn a considerable amount of money. The money you earn will be paid to you in cash at the end of the session.

In case you have any questions while reading the instructions, please raise your hand and the supervisor will come to help you.

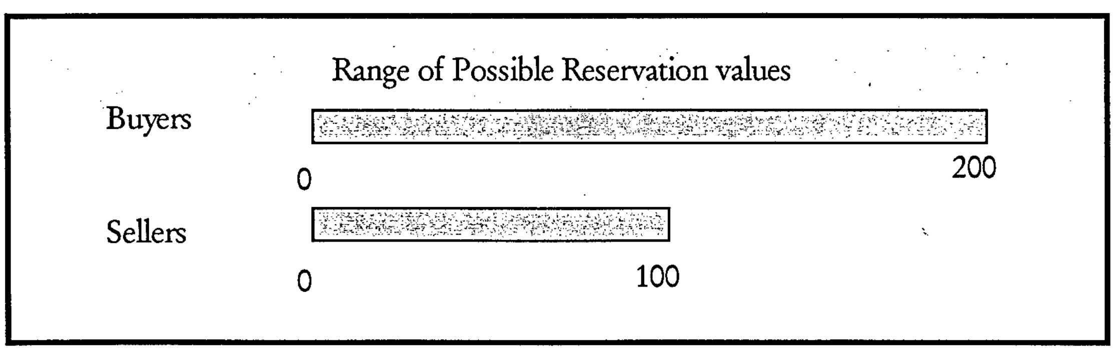
<u>Description of the task</u>

Before the session begins, the subjects in the Laboratory will be divided randomly into two equal size groups of Buyers and Sellers.

You will participate in 50 trials. On each trial, a Buyer and a Seller will be randomly paired, and will bargain on the price of an unspecified object. Since you will communicate with each other via the computer, you will not know your co-bargainer's identity nor will he know yours. You will play the same role (either a Buyer or Seller) on all trials. However, the identity of your co-bargainer will change randomly from trial to trial.

At the beginning of each trial the computer will display your <u>reservation value</u> for the object. The reservation value represents how much the object is worth to you on this trial. It will change from trial to trial.

Reservation values are determined randomly before each trial. For Buyers, reservation values will range from 0 to 200, with each value in this range equally likely. For Sellers they will range from 0 to 100, with each value in this range equally likely. The ranges will be shown graphically on the computer screen before each bargain begins (see the display below). On each trial, you will know your own reservation value (assigned to you by the computer) but not the exact reservation value of your co-bargainer (you will only know that it is equally likely to be within a certain range).



How do you bargain on the price?

After the computer displays your reservation value, you will have an opportunity to submit a bid (Buyer) or an ask (Seller) for the object. If you are the Buyer, your bid price represents the price you propose to pay for the object, and if you are the Seller, your ask price represents the price you propose to accept for the object.

- If the Seller's ask price is higher than the Buyer's bid price, then no deal is struck and you end this trial in disagreement.
- If the Seller's ask price is equal to or lower than the Buyer's bid price, then a deal is struck and you end this trial in an agreement. The contract price in this case is computed to be halfway between the buyer's bid and the seller's ask prices:

contract price = (buyer's bid price + seller's ask price)/2

Note that on each trial, the buyer and the seller make only a single offer (bid price or ask price). These offers determine whether an agreement is reached, and if so at what contract price. There are no second or third rounds of bidding on any particular trial.

How are your earnings determined on each trial?

- If the trial ends in disagreement (because the Seller's ask price exceeds the Buyer's bid price), then you will earn nothing for this trial.
- If the trial ends in agreement (because the Seller's ask price is equal to or lower than the Buyer's bid price), then your earnings will be computed as follows

Buyer's earnings = (Buyer's reservation value - contract price)

Seller's earnings = (contract price - Seller's reservation value)

For the Buyer, her payoff is the difference between her valuation of the object and the contract price. For the Seller, his payoff is the difference between the contract price and his valuation of the same object.

The following example illustrates the computations:

Suppose the Buyer is assigned a reservation value of 110, and the Seller is assigned a reservation value of 65. If the Buyer bids 90 and the seller asks 80, then an agreement is reached at a contract price of 85 ((90 + 80)/2). Using the formulas given above, the earnings are calculated to be:

Buyer's earnings = (110 - 85) = 25

Seller's earnings = (85 - 65) = 20

Please note the following. If the Buyer, in an effort to increase her payoff, decides to lower her bid price from 90 to 80, while the Seller with a similar motivation to increase his payoff, changes his ask price from 80 to 85, then no deal is struck (because the Buyer's bid price is less than the Seller's ask price), and both players will earn nothing on this trial. Hence, a tradeoff exists for both the Buyer and the Seller. The more money they try to earn by decreasing their bid price (Buyer) or increasing their ask price (Seller), the more likely it is that no agreement will be reached. The key uncertainty is that each player does not know the reservation value of the other. The traders only know the range from which these prices are randomly selected.

Procedure

You will play a total of 50 trials. Each trial follows the same sequence: First, the computer will randomly match you with another trader of the opposite type, and will display your reservation value for the object (you will not know your co-bargainer's reservation value, only that it is equally likely to be within a certain range). Next, you will be asked to submit your bid price (Buyer) or ask price (Seller). After both bargainers submit their offers, the computer will inform you of your co-bargainer's offer, and calculate your payoff if an agreement is reached. If an agreement is not reached, your payoff on this trial is zero. After you review your payoffs, you will move to the next trial, if it is not the last one.

Payment at the end of the session

At the end of the session, the computer will sum up all your earnings from the 50 trials. The supervisor will pay you in cash this amount divided by 100.

Please raise your hand to indicate to the supervisor that you have completed reading the instructions. The supervisor will then set your computer for the game. Please be patient; the game will start when everyone is ready.

APPENDIX C. INSTRUCTIONS, PARTIAL BONUS

This study investigates bargaining between a buyer and seller. If you make good decisions, you may earn a considerable amount of money. The money you earn will be paid to you in cash at the end of the session.

In case you have any questions after reading the instructions, please raise your hand and the supervisor will come to answer them.

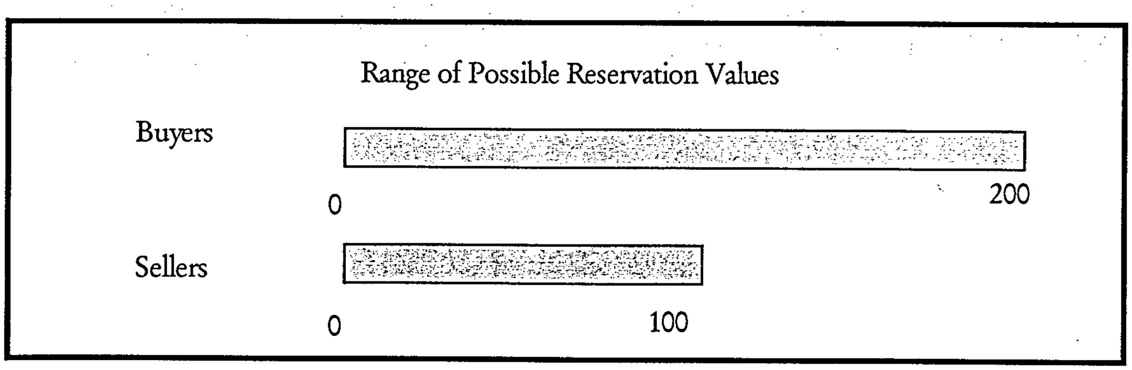
Description of the task

Before the session begins, the subjects in the laboratory will be divided randomly into two equal size groups of buyers and sellers.

You will participate in 50 trials. On each trial, a buyer and a seller will be randomly paired, and will bargain on the price of an unspecified object. Since you will communicate with each other via the computer, you will not know your co-bargainer's identity nor will he or she know yours. You will play the same role (either a buyer or seller) on all 50 trials. However, the identity of your co-bargainer will be changed randomly from trial to trial.

At the beginning of each trial the computer will display your reservation value for the object. The reservation value represents how much the object is worth to you on this trial. If you are the buyer, the reservation value is the most you are willing to bid for it. If you are the seller, your reservation value is the least you are willing to ask for it.

Reservation values are determined randomly before each trial. For buyers, reservation values will range from 0 to 200, with each value in this range equally likely. For sellers, they will range from 0 to 100, with each value in this range equally likely. The ranges will be shown graphically on the computer screen before each bargain begins (see the display below). On each trial, you will know your own reservation value (assigned to you by the computer) but not the reservation value of your co-bargainer (his or her reservation value will be drawn from the range below).



How do you bargain on the price?

After the computer displays your reservation value, you will have an opportunity to submit an offer to buy (buyer) or an offer to sell (seller) the object. If you are the buyer, your offer represents the price you propose to pay for the object, and if you are the seller, your offer represents the price you propose to accept for the object.

- If the seller's offer is higher than the buyer's offer, then no deal will be struck and you will end this trial in disagreement.
- If the seller's offer is equal to or lower than the buyer's offer, then a deal will be struck and you will end this trial in an agreement. The contract price in this case is computed to be halfway between the buyer's offer and the seller's offer:

contract price = (buyer's offer + seller's offer)/2

Note that on each trial, the buyer and the seller make only a single offer (offer to buy by the buyer or offer to sell by the seller). These two offers determine whether an agreement is reached, and if so the contract price. There are no second or third rounds of bargaining on any trial.

How are your earnings determined on each trial?

- If the trial ends in disagreement (because the seller's offer exceeds the buyer's offer price), then you will earn nothing for this trial.
- If the trial ends in agreement (because the seller's offer is equal to or lower than the buyer's offer), then your earnings will be the sum of two components that are determined by the following formulas:

Buyer's earnings = (buyer's reservation value - contract price)

+ (buyer's offer – seller's offer)/4

Seller's earnings = (contract price - seller's reservation value)

+ (buyer's offer – seller's offer)/4

For the buyer, the first component is the difference between her valuation of the object and the contract price. For the seller, the first component is the difference between the contract price and his valuation of the same object. The second component is the same for both traders. It is simply a fraction (25% in this case) of the difference between the buyer's and seller's offers.

The following example illustrates the computations:

Suppose the buyer is assigned a reservation value of 110, and the seller is assigned a reservation price of 65. If the buyer bids 90 and the seller asks 80, then an agreement is reached at a contract price of 85 ((90 + 80)/2). Using the formulas given above, the earnings are calculated to be:

$$\text{Buyer's earnings} = (110 - 85) + (90 - 80)/4 = 25 + 2.5 = 27.5$$

$$\text{Seller's earnings} = (85 - 65) + (90 - 80)/4 = 20 + 2.5 = 22.5$$

Please note the following. In the previous example, if the buyer (in an effort to increase her payoff) decreases her offer from 90 to 80, while the seller (with a similar motivation to increase his payoff) increases his offer from 80 to 85, then no deal is struck (because the buyer's offer is less than the seller's offer). In this case, both players will earn nothing on this trial. Hence, a tradeoff exists for both the buyer and seller. The more money they try to earn by decreasing their offer to buy (buyer) or increasing their offer to sell (seller), the more likely it is that no agreement will be reached. The key uncertainty is that each player does not know the reservation value of the other. The traders only know the range from which these values are randomly drawn. Note, too, that a buyer can lose money if her offer to buy is above her reservation value. Similarly, a seller can lose money if his offer to sell is below his reservation value. Otherwise, no trader can lose money.

Procedure

You will play a total of 50 trials. Each trial follows the same sequence. First, the computer will randomly match you with another trader of the opposite type, and will display your reservation value for the object. (Remember that you will not know your co-bargainer's reservation value, only that it is equally likely to be within a certain range.) Next, you will be asked to submit your offer. After all the bargainers submit their offers, the computer will inform you of your co-bargainer's offer, and calculate your payoff if an agreement is reached. If an agreement is not reached, your payoff for this trial will be zero. After you review your payoffs, you will move to the next trial, if it is not the last in the sequence.

Payment at the end of the session

At the end of the session, the computer will sum up all your earnings from the 50 trials. The supervisor will pay you in cash this amount divided by 100.

Please look up to indicate to the supervisor that you have completed reading the instructions. The supervisor will start the experiment in just a few minutes.

APPENDIX D. INSTRUCTIONS, FULL BONUS

This study investigates bargaining between a buyer and seller. If you make good decisions, you may earn a considerable amount of money. The money you earn will be paid to you in cash at the end of the session.

In case you have any questions after reading the instructions, please raise your hand and the supervisor will come to answer them.

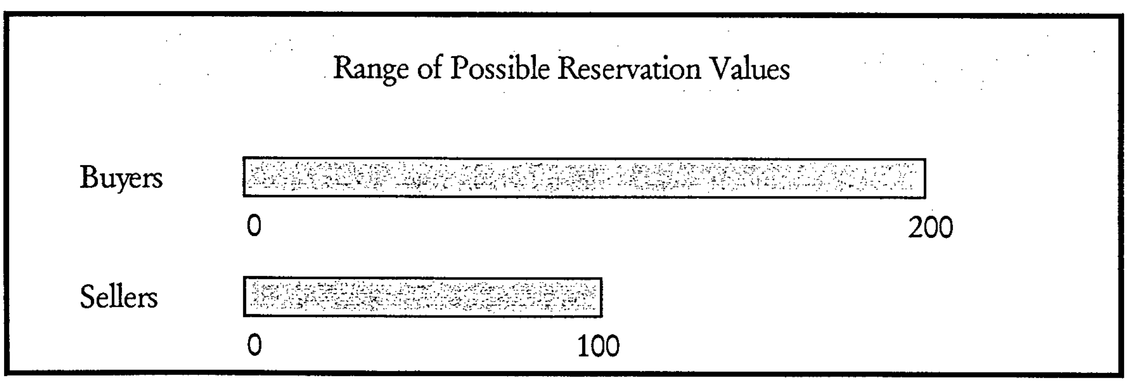
<u>Description of the task</u>

Before the session begins, the subjects in the laboratory will be divided randomly into two equal size groups of buyers and sellers.

You will participate in 50 trials. On each trial, a buyer and a seller will be randomly paired, and will bargain on the price of an unspecified object. Since you will communicate with each other via the computer, you will not know your co-bargainer's identity nor will he or she know yours. You will play the same role (either a buyer or seller) on all 50 trials. However, the identity of your co-bargainer will be changed randomly from trial to trial.

At the beginning of each trial the computer will display your <u>reservation value</u> for the object. The reservation value represents how much the object is worth to you on this trial. If you are the buyer, the reservation value is the most you are willing to bid for it. If you are the seller, your reservation value is the least you are willing to ask for it.

Reservation values are determined randomly before each trial. For buyers, reservation values will range from 0 to 200, with each value in this range equally likely. For sellers, they will range from 0 to 100, with each value in this range equally likely. The ranges will be shown graphically on the computer screen before each bargain begins (see the display below). On each trial, you will know your own reservation value (assigned to you by the computer) but not the reservation value of your co-bargainer (his or her reservation value will be drawn from the range below).



How do you bargain on the price?

After the computer displays your reservation value, you will have an opportunity to submit an offer to buy (buyer) or an offer to sell (seller) the object. If you are the buyer, your offer represents the price you propose to pay for the object, and if you are the seller, your offer represents the price you propose to accept for the object.

- If the seller's offer is higher than the buyer's offer, then no deal will be struck and you will end this trial in disagreement.
- If the seller's offer is equal to or lower than the buyer's offer, then a deal will be struck and you will end this trial in an agreement. The contract price in this case is computed to be halfway between the buyer's offer and the seller's offer:

$$\text{contract price} = (\text{buyer's offer} + \text{seller's offer})/2$$

Note that on each trial, the buyer and the seller make only a single offer (offer to buy by the buyer or offer to sell by the seller). These two offers determine whether an agreement is reached, and if so the contract price. There are no second or third rounds of bargaining on any trial.

How are your earnings determined on each trial?

- If the trial ends in disagreement (because the seller's offer exceeds the buyer's offer price), then you will earn nothing for this trial.
- If the trial ends in agreement (because the seller's offer is equal to or lower than the buyer's offer), then your earnings will be the sum of two components that are determined by the following formulas:

$$\text{Buyer's earnings} = (\text{buyer's reservation value} - \text{contract price})$$

$$+ (\text{buyer's offer} - \text{seller's offer})/2$$

$$\text{Seller's earnings} = (\text{contract price} - \text{seller's reservation value})$$

$$+ (\text{buyer's offer} - \text{seller's offer})/2$$

For the buyer, the first component is the difference between her valuation of the object and the contract price. For the seller, the first component is the difference between the contract price and his valuation of the same object. The second component is the same for both traders. It is simply a fraction (50% in this case) of the difference between the buyer's and seller's offers.

The following example illustrates the computations:

Suppose the buyer is assigned a reservation value of 110, and the seller is assigned a reservation price of 65. If the buyer bids 90 and the seller asks 80, then an agreement is reached at a contract price of 85 (add the offers and divide by two; in this case, (90 + 80)/2). Using the formulas from the previous page, the earnings are calculated to be:

Buyer's earnings = (110 - 85) + (90 – 80)/2 = 25 + 5 = 30

Seller's earnings = (85 - 65) + (90 – 80)/2 = 20 + 5 = 25

Please note the following. In the previous example, if the buyer (in an effort to increase her payoff) decreases her offer from 90 to 80, while the seller (with a similar motivation to increase his payoff) increases his offer from 80 to 85, then no deal is struck (because the buyer's offer is less than the seller's offer). In this case, both players will earn nothing on this trial. Hence, a tradeoff exists for both the buyer and seller. The more money each tries to earn by decreasing his or her offer to buy (buyer) or increasing his or her offer to sell (seller), the more likely it is that no agreement will be reached. The key uncertainty is that <u>each player does not know the reservation value of the other</u>. The traders only know the range from which these values are randomly drawn. Note, too, that a buyer can lose money if her offer to buy is above her reservation value. Similarly, it is possible for a seller to lose money if his offer to sell is below his reservation value. Otherwise, no trader can lose money.

<u>Procedure</u>

You will play a total of 50 trials. Each trial follows the same sequence. First, the computer will randomly match you with another trader of the opposite type, and will display your <u>reservation value</u> for the object. (Remember that you will not know your co-bargainer's reservation value, only that it is equally likely to be within a certain range.) Next, you will be asked to submit your offer. After all the bargainers submit their offers, the computer will inform you of your co-bargainer's offer, and calculate your payoff if an agreement is reached. If an agreement is not reached, your payoff for this trial will be zero. After you review your payoffs, you will move to the next trial, if it is not the last in the sequence.

<u>Payment at the end of the session</u>

At the end of the session, the computer will sum up all your earnings in francs from the 50 trials. The supervisor will then pay you in cash this amount divided by 100.

Please look up to indicate to the supervisor that you have completed reading the instructions. We will start the experiment in just a few minutes.

APPENDIX E. INSTRUCTIONS, REFRAMED FULL BONUS

This study investigates bargaining between a buyer and seller. If you make good decisions, you may earn a considerable amount of money. Your earnings will be converted into dollars and paid to you in cash immediately after the experiment.

In case you have any questions after reading the instructions, please raise your hand and the supervisor will come to answer them.

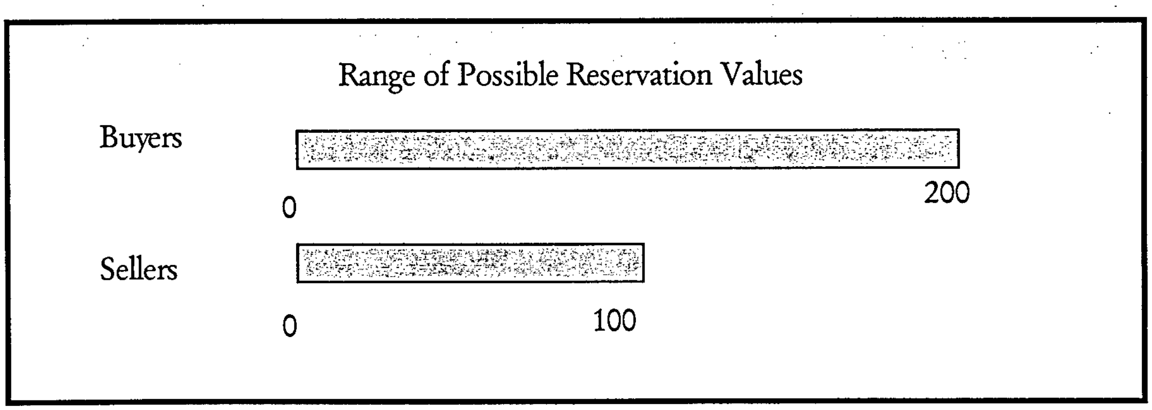
Description of the task

Before the session begins, the subjects in the laboratory will be divided randomly into two equal size groups of buyers and sellers. Once you are assigned a particular role, you will maintain this role throughout the duration of the experiment.

You will participate in 50 trials. On each trial, a buyer and a seller will be randomly paired, and will bargain on the price of an unspecified object. Since you will communicate with each other via the computer, you will not know your co-bargainer's identity nor will he or she know yours. However, the identity of your co-bargainer will be changed randomly from trial to trial.

At the beginning of each trial the computer will display your reservation value for the object. The reservation value represents how much the object is worth to you on this trial. If you are the buyer, the reservation value is the most you are willing to bid for it. If you are the seller, your reservation value is the least you are willing to ask for it.

Reservation values are determined randomly before each trial. For buyers, reservation values will range from 0 to 200, with each value in this range equally likely. For sellers, they will range from 0 to 100, with each value in this range equally likely. The ranges will be shown graphically on the computer screen before each bargain begins (see the display below). On each trial, you will know your own reservation value (assigned to you by the computer) but not the reservation value of your co-bargainer (his or her reservation value will be drawn from the range below).



How do you bargain on the price?

After the computer displays your reservation value, you will have an opportunity to submit an offer to buy (buyer) or an offer to sell (seller). If you are the buyer, your offer represents the price you propose to pay for the object, and if you are the seller, your offer represents the price you propose to accept for the object.

- If the seller's offer to sell is higher than the buyer's offer to buy, then no deal will be made and you will end this trial in disagreement.
- If the seller's offer to sell is equal to or lower than the buyer's offer to buy, then a deal will be made and you will end this trial in an agreement.

Note that on each trial, the buyer and the seller make only a single offer. These two offers determine whether an agreement is reached, and if so, jointly determine each other's earnings. There are no second or third rounds of bargaining on any trial.

How are your earnings determined on each trial?

During this experiment, your offer will only be important to you in determining whether or not a deal is made. If no deal is made, neither you nor your co-bargainer will earn anything. If a deal is made, your offer will have no effect on how much you earn. It will only affect your co-bargainer's earnings. The earnings formulae are:

Buyer's earnings = Buyer's reservation value – Seller's offer
Seller's earnings = Buyer's offer – Seller's reservation value

Thus, neither player's offer will affect his/her earnings. If a deal is reached, your offer will only have an effect on your co-bargainer's earnings. Likewise, your co-bargainer's offer will have no effect on his/her earnings; it will only affect your earnings.

The following example illustrates the earnings computations:

Suppose the buyer is randomly assigned a reservation value of 110, and the seller is randomly assigned a reservation value of 65. If the buyer submits an offer to buy at 90 and the seller submits an offer to sell at 80, a deal is made since the buyer's offer is greater (90 ≥ 80) the seller's offer. Thus, the earnings are calculated to be:

Buyer's earnings = 110 - 80 = 30

Seller's earnings = 90 - 65 = 25

Please note the following. In the previous example, if the buyer decreases her offer from 90 to 80, while the seller increases his offer from 80 to 85, then no deal is struck (because the buyer's offer is less than the seller's offer.) In this case, both players will earn nothing on this trial.

Procedure

You will play a total of 50 trials. Each trial follows the same sequence. First, the computer will randomly match you with another trader of the opposite type, and will display your reservation value for the object. (Remember that you will not know your co-bargainer's reservation value, only that it is equally likely to be within a certain range.) Next, you will be asked to submit your offer. After all the bargainers submit their offers, the computer will inform you of your co-bargainer's offer, and calculate your payoff if an agreement is reached. If an agreement is not reached, your payoff for this trial will be zero. After you review your payoffs, you will move to the next trial, if it is not the last in the sequence.

Payment at the end of the session

At the end of the session, the computer will sum up all your earnings in francs (a fictitious currency used in the experiment) from the 50 trials. The experiment supervisor will then pay you in cash this amount divided by 200.

Please look up to indicate to the supervisor that you have completed reading the instructions. We will start the experiment in just a few minutes.

APPENDIX F. INSTRUCTIONS, TWO-STAGE

The present experiment is designed to study two-person bargaining between a buyer and seller. If you make good decisions, you may earn a considerable amount of money. The money you earn will be paid to you in cash at the end of the session.

In case you have any questions while reading the instructions, please raise your hand and the supervisor will come to help you.

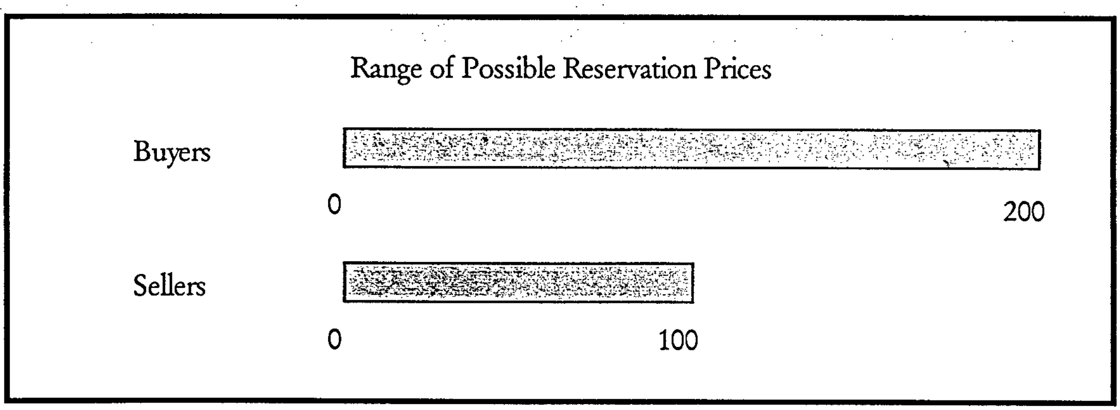
Description of the task

Before the session begins, the subjects in the Laboratory will be divided randomly into two equal size groups of Buyers and Sellers.

You will participate in 50 trials. On each trial, a Buyer and Seller will be randomly paired and then bargain on the price of an unspecified object. Since you will communicate with each other via the computer, you will not know your co-bargainer's identity nor will he/she know yours. You will play the same role (either a Buyer or Seller) on all trials. However, the identity of your co-bargainer will be changed randomly from trial to trial.

At the beginning of each trial the computer will display your reservation value for the object. The reservation value represents how much the object is worth to you on this trial. It will change from trial to trial.

Reservation values (stated in a fictitious currency called "francs") are determined randomly before each trial. For Buyers, reservation prices will range from 0 to 200 francs, with each value in this range equally likely. For Sellers they will range from 0 to 100 francs, with each value in this range equally likely. The ranges will be shown graphically on the computer screen before each bargain begins (see the display below). On each trial, you will know your own reservation value (assigned to you by the computer) but not the exact reservation value of your co-bargainer (you will only know that it is equally likely to be within a certain range).



How do you bargain on the price?

Each trial includes at most two rounds of play.

Round 1: On round 1, after the computer displays your reservation value, you will have an opportunity to make a bid price (Buyer) or ask price (Seller) for the object. If you are the Buyer, your bid price represents the price you propose to pay for the object. If you are the Seller, your ask price represents the price you propose to accept for the object.

- If the Seller's ask price is higher than the Buyer's bid price, then no deal will be struck on round 1 and both you and your co-bargainer will move to the second round of the same trial.

- If the Seller's ask price is equal to or lower than the Buyer's bid price, then a deal will be struck and you will end this trial in an agreement. The contract price in this case is computed to be halfway between the buyer's bid and the seller's ask prices:

  contract price = (buyer's bid price + seller's ask price)/2

Round 2: Round 2 has the same structure as round 1 with the only exception that if no deal is struck, the trial ends in disagreement (and zero payoff to both traders).

In summary, on each trial, the buyer and seller make at most two decisions (bid price for Buyer or ask price for Seller). These decisions determine whether an agreement is reached, and if so at what contract price. An agreement may be reached on round 1. If no agreement is reached on round 1, another opportunity to reach an agreement is provided on round 2. If round 2 is reached, it may be concluded with either an agreement or disagreement.

How are you earnings determined on each trial?

- If the trial ends in disagreement (because the Seller's ask price exceeds the Buyer's bid price on both rounds of play), then you will earn nothing for this trial.

- If the trial ends (on either round 1 or 2) in agreement (because the Seller's ask price is equal to or lower than the Buyer's bid price), then your earnings will be determined by the following formulas:

Buyer's earnings = (Buyer's reservation price - contract price)

Seller's earnings = (contract price - Seller's reservation price)

For the Buyer, her earnings are the difference between her valuation of the object and the contract price. For the Seller, his earnings are the difference between the contract price and his valuation of the same object.

Example: The following example illustrates the computations:

Suppose the Buyer is assigned a reservation price of 110 francs, and the Seller is assigned a reservation price of 65. francs If the Buyer bids 90 francs and the seller asks 80 francs (on either round 1 or round 2), then an agreement is reached at a contract price of 85 francs ((90 + 80)/2). Using the formulas given above, the earnings are calculated to be:

$$\text{Buyer's earnings} = (110 - 85) = 25$$

$$\text{Seller's earnings} = (85 - 65) = 20$$

Please note the following. If the Buyer (in an effort to increase her payoff) decides to lower her bid price from 90 to 80, while the Seller (with a similar motivation to increase his payoff) changes his ask price from 80 to 85, then no deal is struck (because the Buyer's bid price is less than the Seller's ask price). In this case, both traders will earn nothing on this trial. Hence, a tradeoff exists for both the Buyer and the Seller. The more money they try to earn by decreasing their bid price (Buyer) or increasing their ask price (Seller), the more likely it is that no agreement will be reached. The key uncertainty is that each player does not know the reservation price of the other. The traders only know the range from which these prices are randomly selected.

Procedure

You will play a total of 50 trials. Each trial follows the same sequence: First, the computer will randomly match you with another trader of the opposite type, and will display your reservation value for the object (you will not know your co-bargainer's reservation price, only that it is equally likely to be included in a certain range). Next, you will be asked to submit your bid price (Buyer) or ask price (Seller). After both bargainers submit their offers, the computer will inform you of your co-bargainer's offer, and calculate your payoff if an agreement is reached. If an agreement is not reached, you will have a second (and last) opportunity to strike a deal on the second round of the same trial. If round 2 ends with disagreement, your payoff for the trial is zero. After you review your payoffs, you will move to the next trial, if it is not the last one.

Payment at the end of the session

At the end of the session, the computer will sum up all your earnings for the 50 trials. The supervisor will then pay you your earnings at the rate of 80 francs = $1.00. Please raise your hand to indicate to the supervisor that you have completed reading the instructions. The supervisor will then set your computer for the game. Please be patient; the game will start when everyone is ready.

APPENDIX G. INSTRUCTIONS, VARYING-k, CONDITION BS

This study investigates bargaining between a buyer and seller. If you make good decisions, you may earn a considerable amount of money. The money you earn will be paid to you in cash at the end of the session. A research foundation has contributed the funds to support this research.

In case you have any questions after reading the instructions, please raise your hand and the supervisor will come to answer them.

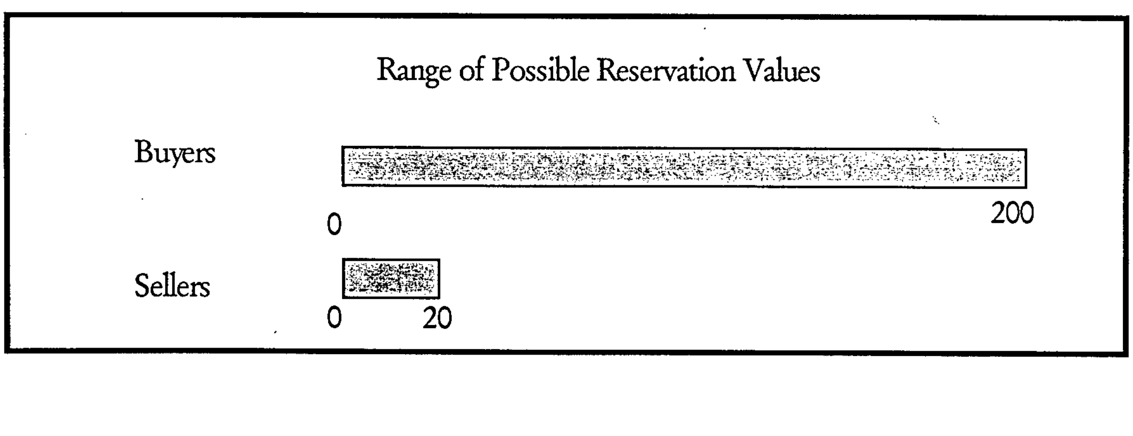
<u>Description of the task</u>

Before the session begins, the subjects in the laboratory will be divided randomly into two equal size groups of buyers and sellers.

You will participate in 50 trials. On each trial, a buyer and a seller will be randomly paired, and will bargain on the price of an unspecified object. Since you will communicate with each other via the computer, you will not know your co-bargainer's identity nor will he or she know yours. You will play the same role (either a buyer or seller) on all 50 trials. However, the identity of your co-bargainer will be changed randomly from trial to trial.

At the beginning of each trial the computer will display your <u>reservation value</u> for the object. The reservation value represents how much the object is worth to you on this trial. If you are the buyer, your reservation value is the most you are willing to bid for it. If you are the seller, your reservation value is the least you are willing to ask for it.

Reservation values are determined randomly before each trial. For buyers, reservation values will range from 0 to 200, with each value in this range equally likely. For sellers, reservation values will range from 0 to 20, with each value in this range equally likely. The ranges will be shown graphically on the computer screen before each bargain begins (see the display below). On each trial, you will know your own reservation value (assigned to you by the computer) but not the reservation value of your co-bargainer (his or her reservation value will be drawn from the range below).



How do you bargain on the price?

After the computer displays your reservation value, you will have an opportunity to submit an offer to buy (buyer) or an offer to sell (seller) the object. If you are the buyer, your offer represents the price you propose to pay for the object. If you are the seller, your offer represents the price you propose to accept for the object.

- If the seller's offer is higher than the buyer's offer, then no deal will be struck and both of you will end this trial in disagreement.
- If the seller's offer is equal to or lower than the buyer's offer, then a deal will be struck and you will end this trial in an agreement. The *contract price will be the seller's offer*, if a deal is reached.

Note that on each trial, the buyer and the seller make only a single offer (offer to buy by the buyer or offer to sell by the seller). These two offers determine whether an agreement is reached, and if so, the seller's offer will determine the contract price. There are no second or third rounds of bargaining on any trial.

How are your earnings determined on each trial?

- If the trial ends in disagreement (because the seller's offer exceeds the buyer's offer), then you will earn nothing for this trial.
- If the trial ends in agreement (because the seller's offer is equal to or lower than the buyer's offer), then your earnings will be computed by the following formulas:

Buyer's earnings = (buyer's reservation value – seller's offer)

Seller's earnings = (seller's offer - seller's reservation value)

The following example illustrates the computations:

Suppose the buyer is assigned a reservation value of 110, and the seller is assigned a reservation price of 10. If the buyer bids 90 and the seller asks 80, then an agreement will be reached. The contract price will be set by the seller's offer, 80. Using the formulas from above, the earnings are calculated to be:

Buyer's earnings = (110 - 80) = 30

Seller's earnings = (80 - 10) = 70

The key uncertainty is that each player does not know the reservation value of the other. The traders only know the range from which these values are randomly drawn. Note, too, that a buyer can lose money if her offer to buy is above her reservation value. Similarly, it is possible for a seller to lose money if his offer to sell is below his reservation value. Otherwise, no trader can lose money.

Procedure

You will play a total of 50 trials. Each trial follows the same sequence. First, the computer will randomly match you with another trader of the opposite type, and will display your reservation value for the object. (Remember that you will not know your co-bargainer's reservation value, only that it is equally likely to be within a certain range.) Next, you will be asked to submit your offer. After all the bargainers submit their offers, the computer will inform you of your co-bargainer's offer, and calculate your payoff if an agreement is reached. If an agreement is not reached, your payoff for this trial will be zero. After you review your payoff, you will move to the next trial, if it is not the last in the sequence.

Payment at the end of the session

At the end of the session, the computer will sum up all your earnings from the 50 trials. The supervisor will pay you in cash this amount divided by 100.

Please look up to indicate to the supervisor that you have completed reading the instructions. The supervisor will start the experiment in just a few minutes.

APPENDIX H. INSTRUCTIONS, VARYING-k , CONDITION BB

This study investigates bargaining between a buyer and seller. If you make good decisions, you may earn a considerable amount of money. The money you earn will be paid to you in cash at the end of the session. A research foundation has contributed the funds to support this research.

In case you have any questions after reading the instructions, please raise your hand and the supervisor will come to answer them.

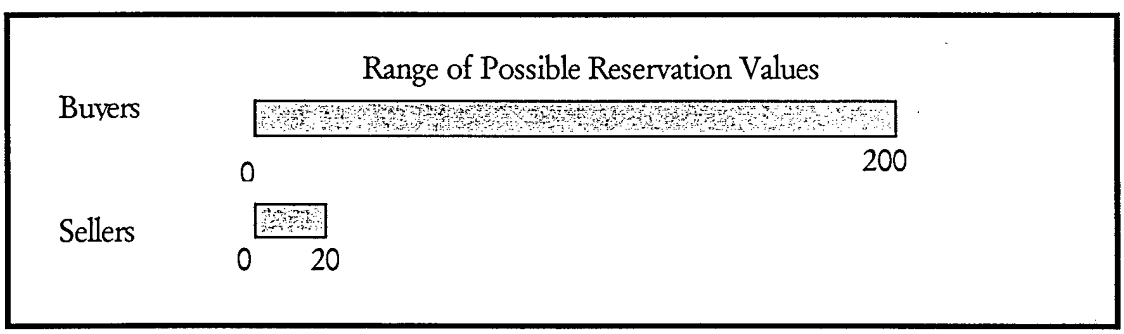
<u>Description of the task</u>

Before the session begins, the subjects in the laboratory will be divided randomly into two equal size groups of buyers and sellers.

You will participate in 50 trials. On each trial, a buyer and a seller will be randomly paired, and will bargain on the price of an unspecified object. Since you will communicate with each other via the computer, you will not know your co-bargainer's identity nor will he or she know yours. You will play the same role (either a buyer or seller) on all 50 trials. However, the identity of your co-bargainer will be changed randomly from trial to trial.

At the beginning of each trial the computer will display your <u>reservation value</u> for the object. The reservation value represents how much the object is worth to you on this trial. If you are the buyer, your reservation value is the most you are willing to bid for it. If you are the seller, your reservation value is the least you are willing to ask for it.

Reservation values are determined randomly before each trial. For buyers, reservation values will range from 0 to 200, with each value in this range equally likely. For sellers, reservation values will range from 0 to 20, with each value in this range equally likely. The ranges will be shown graphically on the computer screen before each bargain begins (see the display below). On each trial, you will know your own reservation value (assigned to you by the computer) but not the reservation value of your co-bargainer (his or her reservation value will be drawn from the range below).



APPENDIX I. INSTRUCTIONS, VARYING-k, CONDITION SS

This study investigates bargaining between a buyer and seller. If you make good decisions, you may earn a considerable amount of money. The money you earn will be paid to you in cash at the end of the session. A research foundation has contributed the funds to support this research.

In case you have any questions after reading the instructions, please raise your hand and the supervisor will come to answer them.

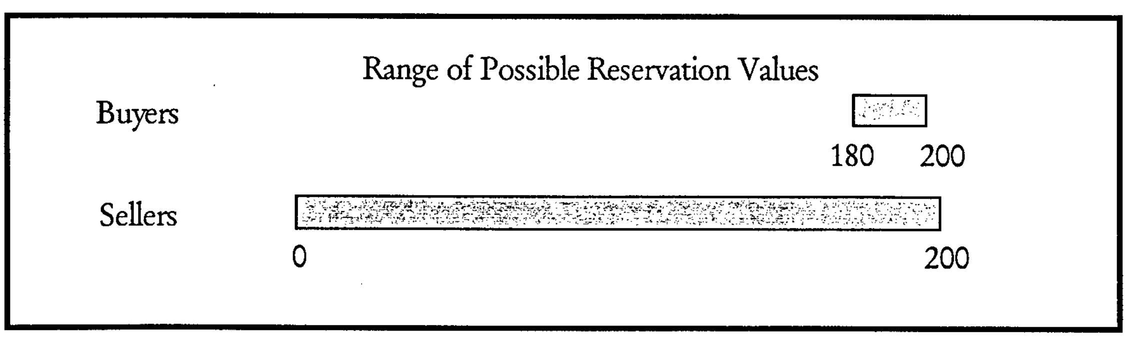
Description of the task

Before the session begins, the subjects in the laboratory will be divided randomly into two equal size groups of buyers and sellers.

You will participate in 50 trials. On each trial, a buyer and a seller will be randomly paired, and will bargain on the price of an unspecified object. Since you will communicate with each other via the computer, you will not know your co-bargainer's identity nor will he or she know yours. You will play the same role (either a buyer or seller) on all 50 trials. However, the identity of your co-bargainer will be changed randomly from trial to trial.

At the beginning of each trial the computer will display your reservation value for the object. The reservation value represents how much the object is worth to you on this trial. If you are the buyer, your reservation value is the most you are willing to bid for it. If you are the seller, your reservation value is the least you are willing to ask for it.

Reservation values are determined randomly before each trial. For buyers, reservation values will range from 180 to 200, with each value in this range equally likely. For sellers, reservation values will range from 0 to 200, with each value in this range equally likely. The ranges will be shown graphically on the computer screen before each bargain begins (see the display below). On each trial, you will know your own reservation value (assigned to you by the computer) but not the reservation value of your co-bargainer (his or her reservation value will be drawn from the range below).



The key uncertainty is that each player does not know the reservation value of the other. The traders only know the range from which these values are randomly drawn. Note, too, that a buyer can lose money if her offer to buy is above her reservation value. Similarly, it is possible for a seller to lose money if his offer to sell is below his reservation value. Otherwise, no trader can lose money.

Procedure

You will play a total of 50 trials. Each trial follows the same sequence. First, the computer will randomly match you with another trader of the opposite type, and will display your reservation value for the object. (Remember that you will not know your co-bargainer's reservation value, only that it is equally likely to be within a certain range.) Next, you will be asked to submit your offer. After all the bargainers submit their offers, the computer will inform you of your co-bargainer's offer, and calculate your payoff if an agreement is reached. If an agreement is not reached, your payoff for this trial will be zero. After you review your payoff, you will move to the next trial, if it is not the last in the sequence.

Payment at the end of the session

At the end of the session, the computer will sum up all your earnings from the 50 trials. The supervisor will pay you in cash this amount divided by 50 (50 francs = $1.00 US).

Please look up to indicate to the supervisor that you have completed reading the instructions. The supervisor will start the experiment in just a few minutes.

APPENDIX J. INSTRUCTIONS, VARYING-k, CONDITION SB

This study investigates bargaining between a buyer and seller. If you make good decisions, you may earn a considerable amount of money. The money you earn will be paid to you in cash at the end of the session. A research foundation has contributed the funds to support this research.

In case you have any questions after reading the instructions, please raise your hand and the supervisor will come to answer them.

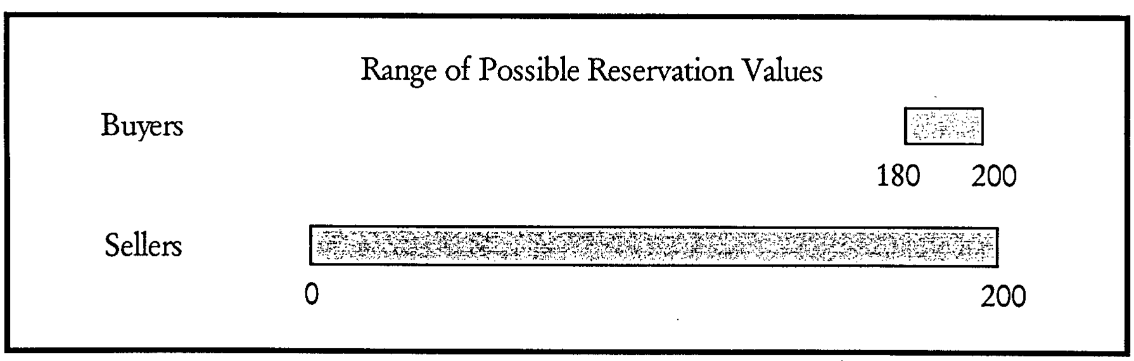
Description of the task

Before the session begins, the subjects in the laboratory will be divided randomly into two equal size groups of buyers and sellers.

You will participate in 50 trials. On each trial, a buyer and a seller will be randomly paired, and will bargain on the price of an unspecified object. Since you will communicate with each other via the computer, you will not know your co-bargainer's identity nor will he or she know yours. You will play the same role (either a buyer or seller) on all 50 trials. However, the identity of your co-bargainer will be changed randomly from trial to trial.

At the beginning of each trial the computer will display your reservation value for the object. The reservation value represents how much the object is worth to you on this trial. If you are the buyer, your reservation value is the most you are willing to bid for it. If you are the seller, your reservation value is the least you are willing to ask for it.

Reservation values are determined randomly before each trial. For buyers, reservation values will range from 180 to 200, with each value in this range equally likely. For sellers, reservation values will range from 0 to 200, with each value in this range equally likely. The ranges will be shown graphically on the computer screen before each bargain begins (see the display below). On each trial, you will know your own reservation value (assigned to you by the computer) but not the reservation value of your co-bargainer (his or her reservation value will be drawn from the range below).



How do you bargain on the price?

After the computer displays your reservation value, you will have an opportunity to submit an offer to buy (buyer) or an offer to sell (seller) the object. If you are the buyer, your offer represents the price you propose to pay for the object, and if you are the seller, your offer represents the price you propose to accept for the object.

- If the seller's offer is higher than the buyer's offer, then no deal will be struck and both of you will end this trial in disagreement.

- If the seller's offer is equal to or lower than the buyer's offer, then a deal will be struck and you will end this trial in an agreement. The *contract price will be the buyer's offer*, if a deal is reached.

Note that on each trial, the buyer and the seller make only a single offer (offer to buy by the buyer or offer to sell by the seller). These two offers determine whether an agreement is reached, and if so, the buyer's offer will determine the contract price. There are no second or third rounds of bargaining on any trial.

How are your earnings determined on each trial?

- If the trial ends in disagreement (because the seller's offer exceeds the buyer's offer), then you will earn nothing for this trial.

- If the trial ends in agreement (because the seller's offer is equal to or lower than the buyer's offer), then your earnings will be computed by the following formulas:

$$\text{Buyer's earnings} = (\text{buyer's reservation value} - \text{buyer's offer})$$

$$\text{Seller's earnings} = (\text{buyer's offer} - \text{seller's reservation value})$$

The following example illustrates the computations:

Suppose the buyer is assigned a reservation value of 190, and the seller is assigned a reservation value of 100. If the buyer bids 160 and the seller asks 150, then an agreement will be reached. The contract price will be set by the buyer's bid, 160. Using the formulas from above, the earnings are calculated to be:

$$\text{Buyer's earnings} = (190 - 160) = 30$$
$$\text{Seller's earnings} = (160 - 100) = 60$$

REFERENCES

1. Atkinson, R. C., Bowers, G. H. and Crothers, E. J. (1965). An Introduction to Mathematical Learning Theory. New York: Wiley.

2. Blackburn, J. M. (1936). Acquisition of skills: An analysis of learning curves. IHRB Report No. 73.

3. Brams, S. J. and Kilgour, D. M. (1996). Bargaining procedures that induce honesty. *Group Decision and Negotiation*, 5, 239-262.

4. Budescu, D. V., Erev, I. And Zwick, R. (1999). Games and Human Behavior: Essays in Honor of Amnon Rapoport. Mahwah, NJ: Lawrence Erlbaum Associates.

5. Bush, R.R. and Mosteller, F. (1955). Stochastic Models for Learning. New York: Wiley.

6. Camerer, C. F., Hsia, D. and Ho, T. (2002). EWA learning in bilateral call markets. In Zwick, R. and Rapoport, Am. (Eds.), Experimental Business Research. Mahwah, NJ: Lawrence Erlbaum Associates.

7. Camerer, C. F. and Ho, T. (1999). Experience weighted attraction learning in normal form games, *Econometrica*, 67, 827-873.

8. Chatterjee, K. and Samuelson, W. (1983). Bargaining under incomplete information. *Operations Research*, 31, 835-851.

9. Coombs, C. H., Dawes, R. M., Tversky, A. (1970). Mathematical Psychology: An Elementary Introduction. Englewood Cliffs, NJ: Prentice-Hall.

10. Daniel, T. E., Seale, D. A., and Rapoport, Am. (1998). Strategic play and adaptive learning in the sealed bid bargaining mechanism. *Journal of Mathematical Psychology*, 42, 133-166.

11. Erev, I. and Roth A. E. (1998). Predicting how people play games: Reinforcement learning in experimental games with unique, mixed strategy equilibria. *American Economic Review*, 88, 848-881.

12. Estes, W. K. (1950). Toward a statistical theory of learning. *Psychological Review*, 57, 94-107.

13. Feltovich, N. (2000). "Reinforcement-based versus belief-based learning models in experimental asymmetric information games." *Econometrica*, 68, 605-641.

40. Siegel, S. and Fouraker, L. E. (1960). Experiments in Bilateral Monopoly. New York: McGraw-Hill.

41. Stein, W. E. (2001). Multistage bargaining. Unpublished manuscript, Lowry-Mays School of Business, Texas A&M University.

42. Stein, W. E. and Parco, J. E. (2001). Comments: Simultaneous offer bargaining. Unpublished manuscript, Eller College of Business and Public Administration, University of Arizona.

43. Smith, V. L. (1994). Economics in the laboratory, *Journal of Economic Perspectives*, 8, 113-131.

44. Suppes, P. and Atkinson, A. C. (1960). Markov Learning Models for Multiperson Interactions. Stanford: Stanford University Press.

45. Thorndike, E. L. (1898). Animal intelligence: An experimental study of the associative processes in animals. *Psychological Monographs*, 2.

46. Thurstone, L. L. (1919). The learning curve equation. *Psychological Monograph*, 26, No. 3.

47. Valley, K. L., Moag, J. and Bazerman, M. H. (1998). 'A matter of trust': Effects of communication on the efficiency and distribution of outcomes. *Journal of Economic Behavior and Organization*, 34, 211-238.

48. von Neumann, J. and Morgenstern, O. (1947). The Theory of Games and Economic Behavior. Princeton: Princeton University Press.

49. Zartman, I. W. (1981). Explaining disengagement. In Jeffrey Z. Rubin (Ed.), Dynamics of Third Party Intervention: Kissinger in the Middle East. New York: Praegar.